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Assessment of Cod in Division 4X in 1999

by

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ABSTRACT

Landings of cod from Division 4X have fluctuated since 1948 between 35,500t and a low of 8,200t in 1998. The quota for 1999 (7,000 t) was prorated to 7,910 t for a 15-month fishing year ending March 31, 2000. Landings to October 1 were 5,500t. In both 1998 and the first half of 1999 landings were spread amongst ages 3-7, with the 1996 year-class contributing more than expected. The summer RV survey catch per tow was down sharply from 1998, and was among the lowest in the time series. The indices at all ages except 7 were below average. The ITQ survey was down substantially from 1998 in weight and also down in numbers, aside from large numbers at ages 0 and 1.

Based on analyses which suggested either natural mortality (M) or survey catchability (q) may have increased in recent years, a variety of ADAPT formulations were explored. No formulation seemed to adequately capture the variability in data from recent years. Two formulations which best represented the trends in recent years were examined in greater detail; both indicate that the spawning stock biomass is currently at a low level. The $F_{0.1}$ yields projected for the fishing year commencing April 1, 2000 are in the range of 4,000t to 6,000t.

RÉSUMÉ

Les débarquements de morue en provenance de la division 4X fluctuent depuis 1948 entre 35 500 t à et 8 200 t en 1998. Le quota de 1999 (7 000 t) a été corrigé au prorata à 7 910 t pour une année de pêche de 15 mois se terminant le 31 mars 2000. Les débarquements au 1er octobre s'élevaient à 5 500 t. Les débarquements de 1998 et ceux de la première demie de 1999 étaient composés de poissons âgés de 3 à 7 ans, l'apport de la classe d'âge de 1996 étant plus élevé que prévu. Les captures par trait de chalut du relevé de recherche d'été ont été nettement inférieures à celles de 1998 et comptaient parmi les plus faibles de la série chronologique. À l'exception de l'âge 7, les indices pour tous les âges étaient inférieurs à la moyenne. Les résultats du relevé par QIT étaient passablement inférieurs à ceux de 1998, tant en poids qu'en nombre, mais les individus d'âges 0 et 1 étaient très nombreux.

Diverses formulations ADAPT ont été étudiées à partir des analyses qui portaient à croire à une augmentation au cours des dernières années de la mortalité naturelle (M) ou de la vulnérabilité à la capture (q) au moment du relevé. Aucune formulation ne permettait d'expliquer convenablement la variabilité des données des dernières années. Les deux formulations qui représentaient le mieux les tendances au cours de ces années ont été examinées de façon plus approfondie : les deux indiquaient une biomasse de géniteurs actuellement faible. Les rendements prévus au niveau $F_{0.1}$ pour l'année de pêche débutant le 1er avril, 2000 se situent dans la gamme des 4 000 t à 6 000 t.

BRIEF HISTORY OF FISHERY AND ASSESSMENT

Prior to 1963, the cod fishery in Division 4X (including the Canadian portion of Division 5Y; Fig. 1) was primarily an inshore fishery. The majority of fishing was done by Canadians, hand-lining and long-lining from small vessels. Between 1957 and 1962, 82-87% of landings were 'inshore', with the remainder split between Canadian and U.S. vessels fishing Browns and LaHave banks (Halliday, 1971). Landings showed a slow decline between 1948 and 1958 from 20,000t to 12,000t (Fig. 2). This decline was attributed primarily to decreases in effort (as fishing was directed more for haddock) but also to declining abundance (Beverton and Hodder, 1962). Foreign and Canadian otter trawlers (OT) began fishing for cod on Browns and LaHave banks in 1962. Due to the increased exploitation on the offshore banks, almost exclusively by OT, landings increased rapidly after 1962, to a maximum of about 35,500t in 1968.

In 1970, landings dropped by 10,000t. This reduction came almost entirely from Canadian and foreign OT landings, while landings by longline (LL) and handline (HL) were largely unaffected. There was no quota for cod in 4X at this time; however, due to the mixed species nature of the groundfish fishery in this area, management measures implemented to regulate fishing on one species inevitably influenced others. The large reduction in cod landings in 1970 has been linked to reductions in fishing effort due to the establishment of quotas for haddock and the closure of Brown's Bank to fishing for March and April, both of which occurred in 1970.

The 4X area was recognized as including a number of separate cod spawning stocks whose distributional boundaries were unclear, thus, it was felt to be inappropriate to assess it as a unit stock. Assessments were conducted for the offshore (primarily Browns and LaHave banks) which was thought to be a discrete stock, and total allowable catch (TAC) was first established for this area in 1975. These TAC's, however, are thought to have had limited impact on landings due to misreporting to the inshore area, where no TAC was in place (Gagne et al., 1983).

Landings throughout much of the 1970's remained in the region of 20,000t-24,000t, increasing to 31,000t by 1980. As a result of this rapid increase in landings to near historically high levels, a TAC was imposed for 4X cod for the first time in 1982. The TAC was set at 30,000t (a level selected to prevent landings from exceeding the maximum landings observed in the early 1980's), and held at this level for 4 years. It had little influence on the landings as a whole, which declined from 32,000t to 21,000t between 1982 and 1985. Aside from the <65ft draggers, no quota group met its allocation from 1983 to 1985 (Campana and Simon, 1986).

The treatment of cod in 4X and 5Yb as a single stock for assessment purposes commenced in 1985. This step was taken partly in response to changes in fishing practices, and partly because mixing between inshore and offshore stocks appeared to be more extensive than had previously been thought. It was not considered possible to separate landings reliably between inshore and offshore areas. This was not a requirement for logbook records, and the increasing range of much of the fleet made the apportioning of landings to inshore or offshore on the basis of tonnage class unreliable. Furthermore, the results from tagging of cod on Browns Bank in spring suggested there may be mixing between inshore and offshore stocks, as well as among inshore spawning groups. It was felt that an assessment which grouped all of 4X would be acceptable due to the mixing occurring among spawning groups, and the mixed nature of the fishery (Campana and Simon, 1986).

With the imposition of more stringent quotas for 4X cod in 1986, there were suggestions that unreported landings and misreporting by species had become serious problems, particularly in 1987 and 1988 (Campana and Simon, 1987; Campana and Hamel, 1990). Reported landings since 1989 are considered more accurate due to increased enforcement, and the institution of mandatory weigh-outs in 1990 (Campana and Hamel, 1992; Gavaris, 1993).

Reported landings remained around 20,000t from 1985-1989, then increased to 28,000t in 1991, and subsequently fell to a low of 9,000t in 1995. The recent reductions in landings are a reflection of the TAC, which declined from 26,000t in 1992 to 9,000t in 1995. The 1999 quota was 7,000t, however, was prorated to 7,900t to include a 15-month fishing year ending March 31, 2000. Landings to October 1 were 5,500t (70%).

SPAWNING AREAS FOR COD IN NAFO DIVISION 4X

Spawning is distributed broadly through the area, both geographically and seasonally. Spawning occurs in the fall (October-December) along the coast of Nova Scotia. This spawning has been described most thoroughly for Halifax Harbour and around Sambro Head to St. Margarets Bay (McKenzie, 1940). Fish aggregating in the deeper water around Sambro Head were the target of a seasonal gill net fishery, which landed roughly 1,000t of cod annually. This fishery began to decline in the early 1980's, and has now all but disappeared. Fish in spawning state have been caught in this area in recent years, and juvenile cod (3-5cm) were captured with a beach seine in Halifax Harbour in May, 1999. Fishermen also continue to catch ripe fish in the Shelburne area in the fall.

Spawning occurs in the spring, primarily on Brown's Bank, but also in other areas. Ripe fish were caught in spring RV surveys conducted in the early 1980's in the Bay of Fundy and around Browns Bank. Fishermen have identified the waters off Digby Neck and Grand Manan as areas where they encounter spawning fish in the spring.

Egg and larval studies support these observations, showing eggs and larvae distributed along the coast of Nova Scotia and into the Bay of Fundy in fall, and on Brown's Bank and in the Bay of Fundy in spring (Neilson and Perley, 1996). The presence of both spring and fall spawners results in a bimodal length frequency for cod at age 1 in the RV and ITQ surveys.

The degree to which fish that spawn in different areas in 4X mix during the year is not clear. Fish tagged in inshore areas show little dispersal from the tagging area, and those tagged in the Bay of Fundy tend to be returned from inside the bay. Fish tagged on Browns Bank in spring, however, disperse widely through the 4X area, with some also recaptured in 5Z. Similarly, some fish tagged on Georges Bank are recaptured in 4X. The proportion of fish tagged on Georges Bank which move into 4X has generally been considered small, however, recent analyses bring this into question (Hunt et al., 1999). Further work on stock structure in this region is required to resolve this issue.

DESCRIPTION OF FISHERY

The fishery in 4X takes place year round. Landings generally peak in June and July, however in recent years landings have been distributed more evenly throughout the year (Table 1). The hook and line fishery accounts for roughly half of the landings, with about 10% more coming from the gill net fishery. The ITQ dragger fleet accounts for the bulk of the remainder, with the EA and TVRP vessels accounting for less than 10% of the landings (Table 2).

The proportion of landings from the winter-spring fishery, prosecuted predominantly by the otter trawl fleet, declined in the mid-1990's, but increased again in 1998. The increase in 1998 was due to fishing directed primarily for haddock along the Shelf edge around Brown's Bank. Late starts in the fixed gear fishery since 1996 had reduced landings early in the year. In 1997 and 1998 TC 1 & 2 hook and line vessels did not catch as high a proportion of their quota in June and July. In some areas this has been a result of poor catch rates; the quota could not be caught in the usual time span. In some areas in 1998 fishermen held off fishing until fall hoping for better inshore fishing due to the low catches experienced by those who started in early summer. In 1999 fishing was reported to have been improved in inshore areas, although it remained poor in some parts of the Bay of Fundy in the summer, and also off Halifax in the fall.

The distribution of landings (Table 3) has also shifted to the west in recent years, with landings from 4Xmno declining to a greater degree than in other areas. In 1997, the proportion of landings coming from the Bay of Fundy was the highest ever, at 48%. There has been little change in the proportion of the hook and line fishery in the Bay of Fundy. The gillnet fishery, however, has switched from a predominantly Scotian Shelf fishery to a fishery split almost equally between the Scotian Shelf and Bay of Fundy (Fig. 3a). Similarly, the otter trawl fishery until recently was concentrated on the Shelf in the spring and winter, moving into the Bay of Fundy in the summer. This fishery was conducted primarily in the Bay of Fundy throughout the year from 1993-1997, resulting in an unusually high proportion of landings coming from the Bay (Fig. 3b). In 1998 and 1999 the winter fishery was again focused primarily on the Shelf, and the proportion of landings coming from the Bay has declined.

Fishermen from around 4X reported mixed success in the cod fishery in 1998. Representatives from both the otter trawl and longline fleets reported that fishing was generally poor for cod east of Browns Bank. In coastal areas throughout 4X fishing was poor in 1998, with some quota groups landing only a small percentage of their quota. Fixed gear groups fishing further offshore and in deeper water, however, reported good fishing. In 1999, most fixed gear groups reported improved fishing. The inshore fishery was better than in the past 3 or 4 years, although it continued to be poor in some areas (Table 4).

Effort by the otter trawl and the tonnage class (TC) 2 and 3 longline and gillnet fleets has declined since the early 1990's, although effort directed for cod increased slightly in 1996 and 1997(Clark et al. 1998). Otter trawl effort did not increase in 1998 (Fig. 4a). Effort remains substantially lower than seen in the early 1990's, however fishing mortality was considered to be unsustainable at that time. It is of some concern that fishing effort is currently higher than in 1994, since fishing mortality has been estimated as well above $F_{0.1}$ for cod and pollock in that year. Effort has also declined substantially in recent years for large gillnet vessels (Fig. 4b).

Effort in days fished is available since 1996 for all vessels (Table 5a). In 1999, a further decline in effort is expected based on an extrapolation from the effort expended in landing the first 41% of the cod quota. The number of vessels actively engaged in the fishery has dropped since 1996 for all gear types (Table 5b). Effort for all fixed gear vessels declined in 1998, but particularly for handliners.

Catch rates for mobile gear have declined annually since 1996 (Table 5c). Fishermen have indicated this is not indicative of abundance, since they have been avoiding cod as the cod quota has dropped and the haddock quota increased. They maintain that cod is primarily taken as bycatch when fishing for other species. The proportion of cod caught by OT in cod directed trips has dropped from 59% of landings in 1996 to 36% of landings in 1999.

Catch rates have increased to the highest level seen in the 4 years examined for all fixed gear types in 1999 (Table 5c). The increase is particularly marked for gillneters, whose catch per day has doubled since 1998. This is in keeping with the observations by fixed gear fishermen of improved success in the fishery in 1999.

CATCH AND WEIGHT AT AGE

Commercial Samples

The 1998 catch at age was based on 54 samples that included otoliths, and 93 additional length frequency samples, an increase in numbers from 1997. However, the necessity for combining some cells in the standard age-length key has continued due to a lack of data (Tables 6 a,b). In the first half of 1999, 18 samples which include otoliths, and an additional 37 length frequency samples are available (Tables 6 c,d). The involvement of a number of industry groups has increased the amount of commercial sampling. Only selected samples have yet been aged for 1999.

Samples were aggregated by area, quarter and gear type (Clark and Brown, 1996). Aggregation by area was done to account for growth differences between the Bay of Fundy (4Xqrs5Yb) and southwest Scotian Shelf (4Xmnop). Landings reported from 4Xu (unspecified area) were apportioned to Bay of Fundy and Scotian Shelf for each statistical district according to known area landings by gear type and tonnage class for that statistical district and quarter. Landings reported from 5Y from 1983 to 1986 for each statistical district were divided between Scotian Shelf and Bay of Fundy according to the same protocol. Misreporting to 5Y from 4X was identified as a problem in these years in past 4X cod assessments (Campana and Simon, 1987, 1988).

Commercial samples are separated into the Bay of Fundy and the Scotian Shelf, however, variability in growth rates and length composition are still found among fishing grounds within each area. Cod in 4Xm in summer are generally smaller and slower growing than in other areas on the Scotian Shelf, and length frequency samples from 4Xo tend to include a greater range of lengths. A number of factors are, therefore, considered when aggregating data for the catch at age.

Due to the variability in fisheries within the region, sampling must be proportional to landings from different fishing grounds in order to ensure that the reconstruction of landings is an accurate reflection of the removals. Observer samples in particular tend to be focused on specific fishing grounds and may not be representative of the wider fishery. Where sampling is not proportional to landings, a finer scale of aggregation is at times required.

For the otter trawl fishery in 1998 there were only 4 samples of the 44 collected by the port sampling program which came from trips where cod was the main species caught. The bulk of cod landings, however, came from cod directed trips. In most cases, the assumption was made that the length frequency for cod in trips where cod was a by-catch was representative of the entire cod fishery; however, samples from monkfish directed trips (250 mm mesh) and redfish trips (90 mm diamond mesh) were down-weighted in the catch at age, as they were thought to be unrepresentative of the bulk of cod landings. Six samples were taken from the otter trawl catch in the Bay of Fundy for the fourth quarter in 1998. Of these, four were taken from cod caught in 4Xq from 90t of landings and one each from 4Xr and 4Xs which contributed 620t of landings. The samples caught in 4Xq were all from haddock-directed trips inside of German Bank, and displayed a truncated length range in comparison to those taken from 4Xrs (Fig. 5). In light of this, the catch at age for 4Xq was derived separate from that for 4Xrs5Y in this quarter.

Sampling from the hook and line fishery came primarily from 4Xp and 4Xn in 1998, although the landings were higher in 4Xo. Those samples taken in 4Xo tended to have a broader length range than samples taken in 4Xn or 4Xp. One sample provided by a South Shore fisherman consisting of 79 fish was used to represent the entire handline fishery in the second and third quarters on the Scotian Shelf. A reconstruction of catch at age for the 1,500t of landings by the hook and line sector in 4Xo based on three samples was investigated, although not used. This resulted in a higher estimate of age 6 fish in the landings.

For 1999 there were no longline or handline samples from 4Xo available, although this remains the area from which the bulk of the landings originate. The reconstructed catch is based on samples from 4Xp and 4Xn only, and may, therefore, underestimate landings of larger, older fish. Such meagre sampling may have led to inaccuracies in the reconstruction of landings.

These cases outline some challenges experienced while attempting to describe the catch at age. With such variability within areas for which the catch is derived, a greater focus on commercial sampling may be needed to maintain an appropriate level of reliability in the catch reconstruction.

The seasonal length-weight parameters used in deriving catch numbers at age (Tables 6 b,d) were those from Campana and Hamel (1992). These parameters were calculated as seasonal averages over the years for which seasonal survey information was available, and have been used since 1985 when seasonal surveys in 4X were discontinued.

Intra-reader age comparison testing was conducted. The level of agreement between separate readings was 92%. Inter-reader testing using samples from the past decade were conducted in 1998 and also showed very high agreement (Clark and Johnston, 1998).

Landings

In 1998, landings were distributed among ages 2-6 with hook and line vessels catching a larger proportion of young fish (Table 7a). In 1999 gillnet catches continue to show the 1992 year-class as a high proportion of their catch, while the 1996 year-class is dominant in both hook and line and otter trawl catches (Table 7b). As the 1992 year class moves through the fishery, the range of ages in the landings continues to increase (Table 8). All ages younger than age 7+ in 1998 (Figs. 6 and 7), and all ages in 1999 (Figs. 9 and 10) appear to be well represented when compared to the long-term mean. The 1992 year-class, however, along with older ages, are a much lower proportion of the landings than anticipated in both 1998 and 1999 (Figs. 8 and 11).

Weights at age for commercial landings from the Bay of Fundy remain higher than average in recent years. The values for the Scotian Shelf are lower in 1998 than they have been in recent years (Table 9). This is likely a result of the inclusion of sampling from 4Xm in the summer in 1998 (an area from which there has been no sampling in recent years), where weights at age are generally lower than in other areas in 4X. The values for the first half of 1999 are included for comparison, and indicate that the weights at age for cod on the Scotian Shelf are again higher than average for most ages in 1999.

Commercial catch at age data from 1980 to 1999 were used in this assessment. While previous assessments have included landings data from before 1980 (Campana and Hamel, 1992), inconsistencies in F's among cohorts within a year, variation in the weights at age, and unusual patterns in catch curves led to the exclusion of the catch at age for the period 1948-1970 in the 1993 assessment (Gavaris, 1993). Furthermore, commercial sampling prior to 1980 was very low, particularly west of Browns Bank, and it has been concluded that the catch history for the Bay of Fundy could not be reliably reconstructed from the commercial samples during this period (Clark, 1995). Catch at age has been derived for the Scotian Shelf to 1971, and a VPA for the Scotian Shelf in 4X has been conducted with these data to provide a longer term population and recruitment series (Clark, 1997).

ABUNDANCE INDICES

Annual stratified random surveys have been conducted in 4X during summer since 1970. As in the 4X cod assessments since 1994, calibration of the VPA for this assessment used survey information collected since 1983, when the RV *Alfred Needler* became the standard survey vessel. Uncertainties in relative fishing power between different survey vessels could have contributed to the residual patterns observed in past assessments (predominantly positive since 1983 and negative before 1983). Furthermore, excluding data prior to 1983 eliminated the retrospective pattern which plagued previous assessments (Gavaris et al, 1994). Based on these considerations, the present assessment was conducted using survey data from 1983-1999.

The distribution of cod was similar to recent years, with no increase in null sets (Fig. 12), however, there were few good catches in the Bay of Fundy. Catch per tow decreased in the Bay of Fundy to about the lowest level observed in 1999. Catch per tow increased slightly in the Scotian Shelf area in 1999, but remained below average (Fig. 13a). Survey catch in 4X as a whole is at its lowest level in weight per tow (Fig. 13b).

Survey results have suggested the 1992 year-class is well above average (Table 10a,b). This year class has had the highest index in the series at ages 4, 5 and 6, and the second highest at age 3. At age 7, however, it is only slightly above average. For all other ages, the 1999 survey was below average. The initial indication given by this survey is that the 1997 year-class is also below average. For the first time in the series, there were no fish caught over age 8 (Table 10b).

The age 2 survey index used in the calibration includes sets at depths <50 fathoms, excluding stratum 490 (St. Mary's Bay). When stratum 490 was removed from the analyses, relative error and bias were reduced in population estimates, and the magnitude of the residuals also decreased (Clark et al., 1995).

The fifth annual 4X ITQ groundfish survey was conducted in July, 1999 using commercial trawlers. The survey employs a fixed station design (although the number of stations has increased over the time series), and involves three vessels using balloon trawls with a 1/2 in. codend liner and rockhopper ground gear. The 4X area was divided into blocks of 100 nm^2 and blocks were selected for sampling prior to sailing. The selection of the exact station location within a block was made by the skipper, allowing them scope to identify a suitable location for trawling (O'Boyle et al., 1995). Once co-ordinates for the sampling location were determined, the location was fixed for subsequent years, eliminating the flexibility which was present in initial selection. Two of the three vessels switched from a 300 to 280 balloon trawl between the first and second year to match what was in use on the vessel fishing in the Bay of Fundy, however the skippers felt this was a minor change and should not affect the catch for these vessels. The potential for differences in fishing power among vessels could complicate some analyses, however, comparisons can be made among years for the 124 stations which were sampled in each year (170 stations for 1996-99; Tables 11a-c).

There is an increase in the number of stations where no cod were caught to 41 in 1999 from 34 in 1998 (Fig. 14). Catches were down primarily in deep stations along the shelf edge. Catches at the majority of stations were below average for the time series (Fig. 15).

The total weight of cod caught in the ITQ survey declined in all areas in 1999 (Table 11a, Fig 13b). Numbers caught increased on the shelf and inshore in 1999, primarily due to catches of small fish (including one tow of over 8000 cod less than 13 cm). The decline in catch weights for this survey since 1996 is apparent and of similar magnitude for the subset of stations occupied in all years (124 stations), or the larger set (170 stations) occupied only since 1996 (Table 11b). As the number of stations included in the analysis is increased in a given year from the original subset of stations, the catch per tow declines. Stations added after the first year tend to be ones where cod abundance is relatively low.

The length frequency of the ITQ survey catch for 1999 on the Scotian Shelf (including only those sets made within Needler strata 470 - 481) peaks at 22 and 31 cm, reflecting numbers at ages 1 and 2 (Fig 16a). This is quite different from what is seen in the RV survey which peaks at 7 and 49cm.(Fig. 17).

The 1999 ITQ survey length frequency for the Bay of Fundy (Fig. 16b; including only those sets made within Needler strata 484 - 495) are generally below average, except for peaks at 25 and 58 cm. The RV survey numbers were quite low at all lengths.

In the Inshore area (Fig. 16c), numbers remained below average in the ITQ survey for most lengths above 31 cm. A single large tow of 7-13 cm fish, and a number of sets around Cape Sable Island with fish in the 19-25 cm range were responsible for the high numbers at lengths reflecting ages 0 and 1.

The relatively high numbers of small fish caught in the ITQ survey may reflect the differences in gear used in the two surveys. The ITQ survey, unlike the RV, uses rock-hopper ground gear. This gear is more effective at catching small cod, since there is no avenue for escape below the foot gear.

Age disaggregated survey indices were calculated for the ITQ survey (Table 11c) using age-length keys from the RV survey. The ALK from the Bay of Fundy was used for the inshore area, since commercial samples taken from the German Bank area, where most of the inshore stations are located, show growth rates similar to the Bay of Fundy cod. These indices track the strong 1992 year-class, with numbers for each age peaking on this year-class. Similar consistency is displayed for the 1991 and 1995 year-classes, which appear weak at all ages. Catches at age 1 were quite variable, and do not appear to be a good predictor of year-class strength at present.

ESTIMATION OF STOCK PARAMETERS

The adaptive framework (Gavaris 1988) was used to calibrate the sequential population analysis with the research survey results using the following data:

$C_{a,t}$ = catch for ages $a=1, 2,..., 11$ during the quarter year time periods beginning at $t=1980,1980.25,1980.5,1980.75,1981,...,1999.25$

$I_{s,a,t}$ = survey abundance index for:
s= RV survey ages $a=2$ *to* 10, *years* $t = 1983.5$ *to* 1999.5 (excluding 1988.5, ages 3 and 4).
ITQ survey ages a = 2 to 9, years t = 1995.5 to1999.5

The summer survey results were compared to mid-year population abundance. Data from ages 3 and 4 from the 1988 summer survey were excluded from the analysis because catchability at these ages appeared to be anomalously high. These data were influential and their inclusion affected population estimates. Estimates obtained when these data were excluded were considered more appropriate (Gavaris, 1993, Clark et al., 1995).

Statistical error in the survey data was assumed to be independent and identically distributed after taking logarithms and the error in the catch at age was assumed negligible. Natural mortality, M, was assumed constant and equal to 0.2 and the fishing mortality rate, F, for age 12 in the final quarter of each year was assumed equal to the average for ages 6, 7 and 8 in the same year and quarter.

A model formulation using ln mid-year population abundances in 1999 (t = *1999.5*) as parameters was employed.

$\phi_{a,1999.5}$ = ln population abundance for ages $a = 2, 3,...,11$, (age 1 abundance assumed equal to the geometric mean recruitment 1993-97), and

κ_a = calibration constants for Canadian summer survey for ages $a = 2,3,...,10$.

ADAPT was used to solve for the parameters by minimizing the objective function

$$Q_{a,t}(\phi,\kappa) = \sum_{a,t} (q_{a,t}(\phi,\kappa))^2 = \sum_{a,t} (\ln(I_{a,t}) - \ln(\kappa_a N_{a,t}(\phi)))^2$$

where the population abundance $N_{a,t}$, is taken at the corresponding time, t, to the survey. Since the sequential population analysis was conducted using quarter year catch at age data, the abundance at the mid-year time, $t = y+0.5$, is directly available.

For t = 1999.5, the population abundances are obtained directly from the parameter estimates,

$$N_{a,1999.5} = exp[\phi_{a,1999.5}].$$

For all other years, y = 1980 to 1999.25, the population abundance was computed using the virtual population analysis algorithm which incorporates the exponential decay model

$$N_{a,t} = N_{a+\Delta t,y+\Delta t}\, exp[(F_{a,t}+M)\Delta t]$$

where the fishing mortality for ages 1 to 10 is obtained by solving the catch equation using a Newton-Raphson algorithm,

$$N_{a,t} = C_{a,t}(F_{a,t} + M)\Delta t / F_{a,t}\Delta t(1 - exp[-(F_{a,t} + M)\Delta t]).$$

Analytical approximations of variance and bias for population abundance estimates and corresponding projected yield were derived following Gavaris (1993).

A second ADAPT formulation is presented following the same protocols, except that only the RV survey numbers for ages 2-7 were used as indices; the ITQ survey was excluded from this model.

ASSESSMENT RESULTS

For each cohort, the terminal population abundance estimates from ADAPT were adjusted for bias (Table 12a) and used to construct the history of the stock status (Table 13a). Commercial weights at age a from the first quarter, and the last quarter of the previous year for age $a-1$ were averaged to provide a beginning of year weight at age, and these were used to calculate beginning of year population biomass (Table 14a & Fig 18a).

Residuals for the RV indices also showed a consistent trend across years (Fig. 19a). Residuals were generally positive for ages 3 and over for years since 1994, and negative for earlier years. Thus, surveys in recent years have been indicating a higher population than is estimated

through the VPA.

The residuals for the ITQ survey are generally small, but show a strong trend at ages 4 and over, with 1995 generally strongly positive, and the last two years negative (Fig. 19a). The indices for this survey show little inter-annual variability at most ages, aside from the strong 1992 year-class. This year-class appears to be very influential in the regression plots and therefore is largely responsible for establishing the q's for this survey. Indices at ages 8 and 9 do not seem to correlate with population numbers, and are likely not reliable at this early point in the survey's evolution.

Fully recruited fishing mortality (ages 4-7) is estimated at 0.4 for 1998; this is higher than was projected in the last assessment, even though over 10% of the quota on which the projection was based went uncaught. The total fishing mortality rate for ages 4 and older has fluctuated around 0.5 (Table 15a). F increased rapidly after 1989, peaking over 1.0 in 1992. This formulation suggests F remained near 1 in 1992 and 1993 as well, before declining in 1995. Biomass at ages 4+ is estimated to have remained at about 20,000t since 1996. This is similar to the more pessimistic option presented in the 1998 assessment (Clark & Johnston, 1998).

The assessment in 1998 included ADAPT formulations which examined the possibility that either survey q's or natural mortality may have changed in recent years. This was partly in response to the mismatch between VPA projection of strong population numbers at ages 6-8, and very low landings at these ages in the fishery, and to high survey Z, or total mortality, estimates (Fig. 20). The survey Z calculated between the 1998 and 1999 surveys is very high. Total mortality estimates have been quite variable in recent years, with a pronounced oscillation, suggestive of high variability in survey catches. Using a two year running average to damp the oscillations gives an increasing trend in Z in recent years (Fig. 20).

A variety of formulations were attempted for this assessment to investigate whether the results from models with changes in q or M might better fit with observations from the fishery. Each of these options estimated population biomass lower than the base model described above, and F higher. These results seemed inconsistent with the declining fishing effort, and with the apparent improvements in the fishery this year.

Formulations which estimated separate q's for recent years in the survey resulted in F's that reached 1.3 in 1994 and had remained in the range of 0.7 to 0.9 since then. The 4+ population biomass was estimated at 11,000t in 1999, which seemed inconsistent with the apparent improvements in the fishery.

A formulations which fixes M at 0.2 prior to 1992, and estimated M in years since 1992 (M estimated at 0.63), produced a pattern in residual plots of generally negative residuals at young ages, and positive at older ages. This also estimated F to have stayed quite high after 1992, despite the large drop in effort noted in the 1998 assessment, and continued to show relatively high mean squared residuals.

A formulation which included indices for ages 2-7 only, from both surveys, resulted in improvements in mean squared residuals, and estimated higher population numbers. This formulation, however, estimated F to be quite high on ages 4 and 5, and then decreasing rapidly at older ages. The dome in the F matrix suggested either that the fishery had changed to such an

extent that older fish were excluded from exploitation, or that the older fish were not actually present, and their presence in the population was an artefact of the model. By removing the survey indices for ages above 7, where low numbers are indicating low population, this model provided nothing to indicate abundance may be low at these ages. The result is high estimates of population number, coupled with low estimates of F. This seems unrealistic.

One final model formulation was investigated in greater detail. The brevity of the ITQ time series, and the lack of range in year class sizes in the five years available, led to the conclusion that q's are likely poorly estimated, and potentially unstable for this survey. The high residual for the first year of the survey suggest that q may have been lower in that year. Changes in gear in the second year, and the trading of a number of stations among the survey vessels may influence the comparability of the 1995 data with that from years since then. These concerns about the stability of survey q's, and patterns in the residuals led to the consideration of a VPA which excluded the ITQ data.

A formulation including ages 2-7 from the RV survey as indices, was investigated (1 index). This 1 index formulation had a much lower mean squared residual (Table 12b), and less of a trend in the residual plots (Fig. 19b). This model estimates population numbers to be low, but stable (Table 13b), a gradually increasing population biomass (Table 14b and Fig 18b), and lower fishing mortalities in recent years (Table 15b), consistent with trends in fishing effort, and reports of improved fishing success. A retrospective analysis for this model shows a marked pattern for the 1990, 1991 and 1992 year-classes, but no pattern for more recent cohorts (Fig. 21). The 1 index model provides estimates of recruitment which are consistently poor since the 1992 year-class (Fig. 22). Fishing mortality is estimated to have dropped dramatically since 1992, and is now below the F seen in the 1980's, though still above the target of 0.2 (Fig 23). The beginning of year population biomass for ages 3 and older (roughly equivalent to the fishable biomass) has increased gradually since 1994 to a recent high in 1999. This is still lower than any biomass seen before 1993. The numbers of fish aged 7+ are estimated as roughly 18% of the 3^{+} numbers. This seems unrealistically high, given the low proportion of the commercial catch these ages comprise. Exploration of the commercial sampling data suggests that older fish may be underestimated in the present catch at age, but not to an extent that would explain the discrepancy between expected proportional catch and what is observed. This indicates their biomass is likely still overestimated, and that the downward retrospective trend indicated for these year-classes will likely continue.

Partial recruitment (PR), derived from the F matrix, appears more strongly domed in recent years for this formulation (Table 16b) than in the base formulation (Table 16a), which includes more ages in the indices. The low survey catches at older ages, which indicate low current population, are excluded, thus the population estimates are higher for these ages. This indicates that population biomass at older ages is likely over-estimated. Projections, therefore, were based on the domed PR estimated for the past 5 years.

The very low survey catches in 1999, particularly for the Bay of Fundy, are obviously a concern. The decline in catch, along with the increase in survey Z, are clearly at odds with the VPA results which indicate a stable or slowly increasing biomass and declining fishing mortality, and with the observations from the commercial fishery. The lack of fish over age 8 in the survey is also of concern. Surveys regularly captured fish at all ages up to 12 in the past. The very high fishing mortality experienced in the early 1990's may be primarily responsible for the lack of older fish.

These patterns in the surveys, and the continued poor fisheries in some areas indicate that a cautious approach to exploitation of this resource is warranted.

Neither of the formulations presented in detail here seems to adequately capture the variability in recent input data for this stock. In both cases, the partial recruitment appears domed in recent years, although there is little reason to anticipate such a change. The formulation including both surveys shows strong patterns in the residuals, and lacks inter-annual stability, with the estimated beginning of 1999 biomass changing by 40% with the inclusion of an additional years data. The formulation which includes the only the RV survey estimates a steady increase in biomass since 1996, in stark contrast to the survey results. Using a domed partial recruitment to estimate the potential yield may amend the discrepancy, but the biomass estimate remains clearly high.

Although neither formulation would seem to be completely reliable, the conclusions from both on the current status of the resource are fairly similar. The stock status is clearly near its historic low, and with recruitment consistently poor in recent years, the short-term prospects remain poor. If the initial indications from the ITQ survey of a strong 1998 year-class prove reliable, then some increase in biomass may be forthcoming in 2 or 3 years time.

Cod spawning stock structure in 4X is quite complex. There are a number of spawning components, and there is also mixing with adjacent areas. With the biomass of cod in 4X generally low, there are clearly some areas where abundance is very low, and others which are not as depleted. The geographic shifts in the fishery have reflected this. It is possible, as suggested in the 1998 assessment, that the reason the RV survey has been overestimating stock abundance in the past 3 or 4 years (as indicated by the predominance of positive residuals in the VPA results) may be that abundance was particularly low in the unsurveyed inshore areas. This is reflected in the fishery which was quite poor in this area from 1995 to 1998. The assumption that abundance trends throughout the management area are reflected by the survey may not have held. The resurgence in the inshore fishery in many areas this year is a positive sign, suggesting the abundance in this area, historically the centre of the fishery, may be increasing from low levels.

A summary of a number of important stock attributes are presented in Table 17. These show that there is currently uncertainty in the stock abundance trends, but that measures of current abundance are uniformly low. Measures of current fishing mortality levels, and trends in exploitation are sharply contradictory. In contrast to the uncertainty in abundance trends, indicators of biological parameters (growth and condition) appear positive, and distribution of the resource is also healthy.

Future Research

Additional work is required to ensure that the best possible use is made of the ITQ survey. Work is also required to better understand the stock structure for cod in this area, and how it affects the assessment. Also, improved monitoring of the commercial fishery is needed to ensure we can accurately reconstruct landings.

PROGNOSIS

Yield projections indicated that the point estimates for projected yield were biased upward by about 10% and had a standard error of about 25% of the mean. As with population abundance estimates, adjusting for bias was considered more appropriate than using the biased point estimate. The incoming year-classes were assumed to be equal to the geometric mean for the last 5 years (Tables 18a,b). Average partial recruitment values for 1990-95 of 0.0, 0.06, 0.42, and 0.76 respectively for ages 1-4 were used in the projections, while ages 5^+ were set as fully recruited.

Assuming that landings in the calendar year reach 6,900t from the 7,900t 15-month quota, the resulting fully recruited fishing mortality will be in the range of .26 to .30 for 1999, as estimated from the two formulations under consideration. The projected yield for 2000 (April 1, 2000 - March 31, 2001) at $F_{0.1}$ is in the range of 4,200t to 5,600t. At this fishing level, the age 4^+ biomass is expected to increase by between 2,000t and 4,000t during the fishing year (Tables 18a,b). This modest increase is due primarily to growth of younger fish.

Further improvements in recruitment are required before any sustained growth in this fishery can be realized. With the concerns expressed about the uncertainty in current stock biomass, it is important to ensure that the exploitation is kept low. To ensure a higher probability of average or better recruitment it is important to ensure that the spawning biomass is high. Given the poor recruitment of recent year-classes, this will require ensuring that fishing mortality is low.

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Table 1. Nominal catch (t) of 4X cod by month.

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	TAC
1980	706	2,188	1,704	2,485	3,317	5,316	3,433	3,346	2,603	2,876	1,547	1,756	31,277	
1981	1,649	2,451	2,529	1,533	2,881	4,093	3,845	4,067	2,253	3,119	1,728	1,373	31,521	
1982	757	2,390	2,569	1,491	3,415	5,109	4,734	3,258	3,540	2,890	1,244	1,737	33,134	30,000
1983	1,713	1,654	1,648	1,888	2,743	5,713	4,554	2,832	3,183	1,787	1,037	719	29,471	30,000
1984	1,798	2,021	752	817	1,796	3,471	3,688	4,567	2,773	1,668	1,201	976	25,528	30,000
1985	779	1,699	956	1,268	1,974	2,586	3,199	2,650	2,737	1,801	787	1,063	21,499	30,000
1986	904	1,633	1,775	1,450	1,437	1,939	2,739	1,995	2,576	1,714	771	1,107	20,040	20,000
1987	1,208	1,837	1,242	1,059	1,870	2,778	2,663	1,821	1,679	1,403	910	535	19,005	18,000
1988	2,104	1,531	535	939	1,620	2,931	3,104	2,122	2,524	1,441	636	1,050	20,537	16,000
1989	2,150	2,347	1,362	1,707	1,292	3,562	1,830	1,772	1,535	1,278	637	413	19,885	13,000
1990	2,619	2,027	707	778	1,560	3,104	3,751	3,123	2,598	1,689	1,158	790	23,904	22,000
1991	2,023	2,651	993	1,666	2,322	3,167	3,963	2,881	2,967	2,208	1,650	1,258	27,749	26,000
1992	2,088	1,740	1,297	1,502	1,685	3,622	3,366	2,803	2,625	2,353	1,478	1,521	26,080	26,000
1993	657	903	994	996	1,617	2,312	2,834	2,221	1,804	1,048	562	78	16,026	16,000
1994	734	972	547	847	824	1,771	2,246	1,503	1,267	1,154	726	454	13,045	14,000
1995	610	229	317	827	574	1,236	1,771	774	1,071	521	276	561	8,767	9,000
1996	503	331	446	531	819	1,755	1,805	1,317	880	887	679	619	10,572	11,000
1997	98	362	378	806	644	1,440	1,779	1,382	1,548	1,424	710	668	11,239	13,000
1998	285	348	402	313	511	941	1,272	953	1,125	770	520	729	8,169	9,300
1999	186	105	124	330	409	1,039	1,250	800					4,243	7,900*

* Jan 1, 98 - Apr 1, 99

Table 2. Nominal catch of 4X cod by gear and tonnage class.

	Otter Trawl					Gill Net		Long Line			Hand		
Year	0&1	2	3	4	5+	0&1	2&3	0&1	2	3+	Line	Misc.	Total
1980	1,322	2,769	4,284	1,042	2,037	2,683	61	8,356	2,360	898	4,198	1,267	31,277
1981	1,165	3,086	2,989	416	1,131	2,871	114	10,302	2,555	1,235	5,174	483	31,521
1982	879	3,159	4,493	563	2,217	3,154	214	9,120	3,465	1,087	4,299	484	33,134
1983	638	4,735	6,306	518	1,118	2,180	235	5,747	2,757	883	3,750	604	29,471
1984	964	4,198	5,904	302	1,513	1,248	220	3,916	2,825	980	3,005	453	25,528
1985	523	3,954	5,562	90	1,185	1,837	161	2,617	1,740	635	2,755	440	21,499
1986	573	3,663	5,123	224	974	1,453	196	2,479	1,918	576	2,490	371	20,040
1987	312	2,645	3,504	531	929	1,968	241	3,075	2,175	499	2,670	456	19,005
1988	454	3,966	3,542	160	467	903	444	3,528	3,149	672	3,081	171	20,537
1989	409	3,933	4,184	67	713	1,254	475	2,915	2,167	623	2,937	208	19,885
1990	505	3,668	3,577	268	170	1,933	692	4,201	2,967	849	4,871	203	23,904
1991	355	4,598	5,805	298	751	2,225	619	4,712	3,679	842	3,737	128	27,749
1992	238	4,494	5,711	143	726	1,811	586	4,455	3,574	719	3,517	106	26,080
1993	176	2,778	3,598	68	241	1,387	523	2,768	1,693	310	2,439	45	16,026
1994	132	2,022	2,343	138	82	993	421	2,837	1,412	231	2,367	67	13,045
1995	100	1,387	1,619	112	75	470	507	1,632	959	182	1,706	18	8,767
1996	92	1,552	2,314	157	103	611	442	1,774	1,306	201	1,914	106	10,572
1997	79	2,094	2,430	136	35	694	471	2,013	1,255	231	1,794	6	11,238
1998	96	1,407	1,892	166	22	429	376	1,663	997	244	879	0	8,169
1999*	56	518	923	53	11	342	336	901	368	52	683	0	4,243

* January 1 - September 1.

Table 3. Nominal catch of 4X and 5Y cod by unit area.

	4Xm	4Xn	4Xo	4Xp	4Xq	4Xr	4Xs	4Xu	5Y	Shelf	Fundy	Foreign	Total
1980	5,205	3,325	9,899	1,561	3,571	4,684	2,278	47	166	20,023	10,712	541	31,276
1981	4,767	2,114	12,097	1,830	2,413	5,072	2,031	419	599	21,051	10,290	179	31,520
1982	5,255	2,922	10,451	2,079	3,715	4,571	2,009	538	1,349	20,956	11,933	245	33,134
1983	3,437	1,690	8,537	2,497	3,160	3,787	1,674	1,826	2,543	16,891	12,258	320	29,469
1984	2,255	2,251	6,192	1,655	2,244	2,959	1,414	3,583	2,698	14,110	11,141	277	25,528
1985	3,006	1,199	5,438	1,026	1,999	2,301	1,511	3,608	1,364	12,236	9,216	47	21,499
1986	2,914	1,762	4,670	544	1,754	1,802	1,500	4,469	557	11,748	8,224	68	20,040
1987	2,676	1,611	4,777	1,131	1,240	858	1,207	5,116	360	12,783	6,179	29	18,991
1988	1,502	1,086	5,458	1,271	1,124	850	1,103	7,990	142	14,814	5,711	11	20,536
1989	1,370	1,019	5,506	2,820	1,360	1,112	915	5,267	478	13,855	5,994	38	19,887
1990	1,846	764	7,915	1,746	2,238	1,721	1,722	5,404	326	15,551	8,119	222	23,892
1991	2,552	1,584	8,963	2,440	2,763	4,243	2,560	2,246	307	17,275	10,383	91	27,749
1992	1,523	1,818	10,347	1,455	2,919	3,352	1,503	2,876	278	17,556	8,515	9	26,080
1993	1,364	1,646	4,845	1,436	1,959	2,428	1,399	760	189	9,924	6,102	0	16,026
1994	828	561	4,414	1,128	1,662	1,883	892	1,540	137	8,321	4,724	0	13,045
1995	293	696	1,737	1,586	1,306	1,032	510	1,528	79	5,349	3,418	0	8,767
1996	466	813	2,787	1,484	1,608	1,659	930	654	171	6,055	4,517	0	10,572
1997	453	837	2,213	1,327	1,793	2,240	1,070	1,303	183	5,943	5,479	0	11,422
1998	477	907	1,634	1,796	983	1,284	606	331	151	5,064	3,105	0	8,169
1999*	200	401	957	907	759	570	258	98	93			0	4,243

*January 1 - September 1

Table 4. Summary of fishery reports for cod in Division 4X in 1999.

Gear Type	Fishery Reports
Handline	Landings off Digby Neck were low overall, but catch per vessel increased. This year was better than the previous two years.
	Poor for Yarmouth.
Longline	(As with handline) Improvement in fishing along the Southern Shore to Cape Sable over the past 3-4 years. Cod were available in coastal waters for the first time in 4 years. Catches were reported to contain a great range of lengths. Around Cape Sable there were high proportions of small fish in coastal areas, but these could be avoided by selecting appropriate fishing grounds. Fish were generally reported as more abundant, and larger in 1999.
	Poor in spring off Saint John.
Gill net	Good off SW bank in Jul.-Aug., catch rate at least doubled that of the previous year. Yielding mainly cod in 1999, this area has traditionally been fished primarily for pollock.
	Catches were good in deep water in the Gulf of Maine in spring.
	Catches were better than recent years off Grand Manan.
	Landings in the fall fishery in eastern 4X were reported to be very poor. Fishermen abandoned the fishery as it was not worth the effort. Some reports of catching less than one fish per string of net.
Otter Trawl	Poor fishing east of Browns Bank. Very good catches on Browns in June when the Bank opened, however, the fish dispersed quickly after that.
	Average fishing for recent years in the Bay of Fundy, with some need to avoid cod to pursue haddock.

Table 5a. Fishing days by gear type.

Year	Gill net	Longline	Handline
1996	4,912	5,210	9,880
1997	6,281	6,179	9,650
1998	4,178	5,352	5,721
1999*	1,544	1,867	1,858
1999**	3,474	4,200	4,180

*1999 effort to Sept., 41% of the fixed gear cod quota had been landed.

**1999 effort adjusted for the entire year

Table 5b. Number of fishing vessels reporting cod landings annually.

Year	Otter trawl	Gill net	Longline	Handline
1996	142	205	528	779
1997	142	197	497	657
1998	129	163	398	422
1999	125	117	312	323

Table 5c. Landings (t) per day fished (per effort hour for otter trawl) for cod in trips where cod was main species caught.

Year	Otter trawl	Gill net	Longline	Handline
1991	0.145			
1992	0.129			
1993	0.990			
1994	0.112			
1995	0.098			
1996	0.111	0.250	0.843	0.237
1997	0.096	0.246	0.787	0.221
1998	0.087	0.268	0.762	0.200
1999	0.075	0.631	0.873	0.240

Table 6a. Construction of Age-Length keys for 4X cod for 1998.

Area	Fundy (4Xqrs5Y)				Shelf (4Xmnop)			
Quarter	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
No. Samples	0	19	8	4	10	3	4	6
No. Aged	0	545	281	155	395	208	201	249
Landings (t)	140	786	1,386	794	895	980	1,965	1,224

Table 6b. Construction of length frequencies for 4X cod for 1998, and age-length keys against which they are matched.

Gear	Quarter	Area	a	b	Number of samples	Number Measured	Landings (t)	ALK used
OT	1	Fundy	0.0081	3.0503	3	669	136	Fundy Q2
GN					0	0	0	
LL					0	0	0 *	
HL					0	0	0	
OT	1	Shelf			19	4,230	756	Shelf Q1
GN					0	0	0	
LL					1	220	139	
HL					0	0	0	
OT	2	Fundy	0.0084	3.0410	7	1,351	499	Fundy Q2
GN					3	579	64	
LL					15	950	124 *	
HL					16	1,182	102	
OT	2	Shelf			4	799	227	Shelf Q2
GN					2	406	211	
LL					16	3,881	288	
HL					0	LL Q2 S #	254	
OT	3	Fundy	0.0087	3.0233	6	1,042	913	Fundy Q3
GN					7	681	199	
LL					1	256	172	
HL					2	307	101	
OT	3	Shelf			2	362	61	Shelf Q3
GN					0	GN Q3 F #	232	
LL					16	2,552	1,279	
HL					3	151	393	
OT	4	Fundy	0.0063	3.1152	6	1,739	711	Fundy Q4
GN					0	GN Q3 F #	25	
LLHL					0	LL Q3 F #	58	
OT	4	Shelf			3	843	280	Shelf Q4
GN					0	GN Q3 F #	73	
LLHL					15	3,084	872	

LF substituted due to absence of commercial sampling for this gear/area/quarter combination

* Landed weight for LL Q1 F (4 t) was added to LL Q2 F.

Table 6c. Construction of Age-Length keys for 4X cod in 1999.

Area	Fundy (4Xqrs5Y)				Shelf (4Xmnop)			
Quarter	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
No. Samples	1	7			5	5		
No. Aged	48	331			220	201		
Landings (t)	88	869			327	871		

Table 6d. Construction of length frequencies for 4X cod for 1999, and age-length keys against which they are matched.

Gear	Quarter	Area	a	b	Number of samples	Number Measured	Landings (t)	ALK used
OT	1	Fundy	0.0081	3.0503	2	604	87	Fundy Q1
GN					0	0	0	
LL					0	LL Q2 F #	1	
HL					0	0	0	
OT	1	Shelf			21	3,942	256	Shelf Q1
GN					0	0	0	
LL					1	235	71	
HL					0	0	0	
OT	2	Fundy	0.0084	3.0410	15	2,968	558	Fundy Q2
GN					0	OT Q2 F #	126	
LL					3	604	81	
HL					4	657	104	
OT	2	Shelf			3	740	180	Shelf Q2
GN					4	920	155	
LL					2	372	264	
HL					0	LL Q2 S #	272	

LF substituted due to absence of commercial sampling for this gear/area/quarter combination.

Table 7a. Landed number (000's) of 4X cod at age by gear type for 1998.

Age	1	2	3	4	5	6	7	8	9	10	11	12
LL+HL	0	142	582	649	357	171	29	7	3	1	2	1
OT	0	92	286	324	218	206	19	9	2	1	1	0
GN	0	0	18	48	40	65	7	3	1	0	0	0

Table 7b. Landed number (000's) of 4X cod at age by gear type for 1999 (Jan.-Jul.)

Age	1	2	3	4	5	6	7	8	9	10	11	12
LL+HL	0	3	152	84	64	29	12	0	0	0	0	0
OT	0	2	185	120	65	36	19	3	0	0	0	0
GN	0	0	10	15	15	9	11	1	1	0	0	0

Table 8. Catch at age (number in thousands) for cod in Division 4X.

Age	1	2	3	4	5	6	7	8	9	10	11	12	2+	3+	4+
1980	0	837	6,054	2,358	1,742	1,135	442	261	91	60	19	17	13,016	12,178	6,124
1981	0	818	3,870	4,265	1,844	1,045	587	297	184	75	39	19	13,042	12,225	8,355
1982	0	904	2,885	4,414	3,060	912	393	279	146	86	41	25	13,145	12,240	9,356
1983	9	1,031	3,689	2,433	2,057	1,205	459	204	120	76	36	10	11,320	10,289	6,600
1984	33	917	2,393	3,081	1,930	965	465	176	63	49	29	18	10,086	9,169	6,776
1985	0	711	1,674	1,569	2,324	1,284	514	194	71	53	18	7	8,419	7,708	6,034
1986	0	251	2,789	1,941	994	1,008	409	200	93	50	23	20	7,778	7,527	4,738
1987	0	861	902	2,053	1,087	523	511	236	140	66	33	9	6,421	5,560	4,659
1988	0	403	3,517	1,659	1,553	656	178	192	85	53	28	6	8,329	7,925	4,408
1989	17	655	2,560	3,656	632	562	163	79	60	19	10	10	8,406	7,751	5,191
1990	0	144	2,863	2,805	2,462	497	279	78	40	38	14	15	9,234	9,090	6,227
1991	2	391	1,535	5,092	1,777	1,364	215	156	32	16	28	15	10,621	10,229	8,694
1992	0	751	3,391	1,878	3,276	878	513	63	50	16	9	4	10,828	10,077	6,685
1993	0	881	3,490	2,045	660	672	186	90	14	14	5	0	8,056	7,176	3,686
1994	0	475	2,280	2,233	887	195	181	42	18	0	2	0	6,314	5,838	3,558
1995	0	135	2,146	1,081	582	130	28	40	11	5	0	0	4,158	4,023	1,877
1996	0	50	883	2,594	441	212	29	16	8	2	1	1	4,237	4,187	3,304
1997	0	59	1,126	1,556	1,193	199	82	16	2	6	1	3	4,243	4,184	3,058
1998	0	234	886	1,021	615	441	54	20	6	2	3	1	3,283	3,049	2,163
1999*	0	5	347	219	144	73	42	4	1	0	0	0	835	830	483

* Landings for January - July 1.

Table 9. Mean weight at age (kg) of cod from commercial landings in two sub-areas of Division 4X.

		1	2	3	4	5	6	7	8	9	10	11	12
	1983		0.76	1.22	1.81	2.50	3.93	6.09	8.22	10.76	11.83	12.22	16.59
	1984		0.96	1.30	1.69	2.34	3.37	4.68	6.83	8.60	11.06	13.21	14.03
	1985		0.60	1.07	1.47	2.00	3.06	4.55	6.70	6.89	9.00	14.16	15.66
	1986		0.78	1.13	1.63	2.21	3.47	4.69	7.15	8.83	8.81	13.11	13.10
	1987		1.23	1.40	1.83	2.61	3.46	4.99	7.33	8.36	10.66	11.80	15.85
Scotian	1988		0.94	1.30	1.90	2.69	3.98	5.23	8.06	9.88	10.93	13.05	16.04
Shelf	1989	0.78	1.23	1.57	2.21	2.75	3.96	4.88	7.86	9.46	11.95	15.04	14.81
	1990		0.82	1.29	1.97	2.86	3.72	5.59	8.10	10.46	11.93	14.12	15.24
	1991		0.76	1.13	1.73	2.50	3.54	5.08	6.44	9.44	11.19	13.73	15.74
	1992		0.78	1.14	1.63	2.58	3.58	4.44	6.50	8.37	12.10	14.50	19.15
	1993		0.68	1.25	1.62	2.24	3.44	4.67	7.01	9.13	10.97	18.08	
	1994		0.76	1.04	1.92	2.41	3.15	4.97	5.21	9.28	15.98	13.56	
	1995		0.86	1.23	1.72	3.26	4.09	4.69	7.23	9.18	13.33	16.33	
	1996		0.75	1.21	2.06	2.96	4.77	5.53	6.39	9.80	12.02	10.12	
	1997		1.17	1.22	1.83	3.31	4.49	6.04	8.83	9.99	11.14	13.58	8.71
	1998		0.86	1.12	1.71	2.54	4.42	4.72	7.33	9.76	9.66	10.83	16.17
	Mean	0.78	0.87	1.23	1.80	2.61	3.78	5.05	7.20	9.26	11.41	13.59	15.09
	1999*		0.56	1.46	2.16	2.99	3.62	5.45	7.08	9.12	12.70	12.10	13.70
	1983	0.38	0.86	1.48	2.18	3.30	4.88	6.38	8.62	9.92	12.19	14.23	20.63
	1984	0.39	0.93	1.62	2.48	3.52	4.67	6.98	7.94	12.10	13.45	4.75	
	1985	0.37	0.84	1.48	2.26	3.43	4.53	6.54	9.45	11.46	15.12	18.23	19.52
	1986	0.37	0.80	1.41	2.33	4.30	6.24	7.36	8.18	9.50	14.25	7.99	11.98
	1987		0.84	1.57	2.56	4.17	5.33	7.04	7.92	7.94	14.31	18.56	
Bay of	1988		0.86	1.46	2.24	4.09	5.36	8.99	10.14	8.89	14.69		
Fundy	1989	0.33	0.76	1.52	2.59	3.60	6.33	7.25	10.32	10.55	14.57		11.66
	1990		1.05	1.69	2.69	3.77	4.37	7.31	8.15	11.32	11.95	12.75	14.74
	1991	0.82	1.04	1.88	2.91	4.26	6.77	8.75	11.02	13.60	14.17	15.10	17.93
	1992		1.18	1.73	2.73	4.49	6.51	8.78	9.93	13.13	14.55	11.10	
	1993		0.90	1.74	2.86	4.74	6.09	7.58	9.18	14.32	16.75	13.85	
	1994		0.98	1.75	3.19	5.72	7.96	9.31	11.61	11.56	-	17.46	
	1995		1.29	1.91	2.78	4.38	6.01	7.76	9.84	12.49	8.57	14.32	
	1996		1.06	1.70	2.85	4.71	6.12	5.97	10.56	11.05			13.19
	1997		1.17	1.73	2.74	4.28	5.77	8.44	10.30	9.18	12.94	11.07	22.55
	1998		1.16	1.99	3.14	4.49	5.91	8.13	9.20	12.75		14.32	
	Mean	0.44	0.98	1.66	2.66	4.20	5.80	7.66	9.52	11.23	13.65	13.36	16.52
	1999*		0.81	1.64	2.76	4.52	5.45	7.26	4.16			9.49	15.50

* January-July 1

Table 10a. Summer groundfish survey indices for cod in Division 4X.

Age	2	3	4	5	6	7	8	9	10
1983	223	4,226	2,369	1,480	946	389	0	77	37
1984	1,385	3,390	2,362	1,820	688	482	63	58	25
1985	1,139	4,331	1,527	1,451	766	483	267	165	13
1986	258	2,920	1,226	314	549	448	217	97	19
1987	1,158	618	1,180	528	260	245	304	75	40
1988	564			1,776	496	210	244	91	38
1989	1,073	3,420	2,549	420	489	108	27	82	37
1990	110	5,523	2,463	2,321	240	414	80	42	0
1991	390	1,131	3,086	1,094	751	128	116	19	21
1992	874	1,569	681	1,710	471	460	124	85	0
1993	350	2,518	925	129	265	52	61	0	6
1994	711	2,739	1,605	449	36	195	88	70	0
1995	350	4,779	1,477	598	274	94	91	34	42
1996*	323	2,048	5,527	880	753	148	0	56	15
1997	211	1,189	1,444	2,462	321	194	100	0	57
1998	456	1,808	1,418	1,022	1,371	225	116	6	0
1999	280	1,291	882	850	194	297	46	0	0

* Includes stations occupied within 4X during survey N246; stations resampled during N247 were excluded. See Clark and Brown, 96.

Table 10b. Summer groundfish survey stratified total numbers for cod in Division 4X.

Age	0	1	2	3	4	5	6	7	8	9	10	11	12+
1970	27	938	1,528	2,426	4,217	1,846	2,546	1,059	497	157	138	13	0
1971	21	363	7,079	3,934	676	1,537	707	1,054	119	0	17	0	0
1972	0	327	1,424	3,165	2,537	712	502	202	538	376	164	22	182
1973	23	114	2,197	1,174	2,141	626	253	155	33	170	63	29	26
1974	111	411	1,004	4,524	1,126	1,665	926	119	0	56	35	44	70
1975	0	1,011	2,864	1,612	2,950	2,442	985	760	158	99	0	112	35
1976	0	152	1,277	2,812	2,306	2,051	888	375	220	67	69	13	26
1977	15	251	2,281	4,211	2,541	789	1,323	325	201	38	27	59	12
1978	23	183	1,068	1,712	2,489	1,345	496	362	93	71	0	0	0
1979	0	2,728	3,521	1,814	1,890	1,764	1,019	439	307	59	62	137	0
1980	2,406	205	910	2,864	1,112	1,052	1,379	390	221	186	0	69	0
1981	62	2,269	2,366	2,387	2,496	1,345	835	470	418	98	91	27	7
1982	73	750	1,831	1,828	1,830	1,481	876	243	260	186	49	31	41
1983	208	141	1,085	4,226	2,369	1,480	946	389	0	77	37	0	6
1984	0	820	5,746	3,390	2,362	1,820	688	482	63	58	25	0	0
1985	69	495	8,760	4,331	1,527	1,451	766	483	267	165	13	0	26
1986	25	768	1,333	2,920	1,226	314	549	448	217	97	19	0	51
1987	6	392	2,348	618	1,180	528	260	245	304	75	40	63	0
1988	260	2,630	3,926	9,246	1,496	1,548	496	210	244	91	38	13	0
1989	309	794	6,089	3,420	2,549	420	489	108	27	82	37	14	0
1990	28	515	873	5,523	2,463	2,321	240	414	80	42	0	21	27
1991	34	614	1,727	1,131	3,086	1,094	751	128	116	19	21	12	0
1992	35	252	2,731	1,569	681	1,710	471	460	124	85	0	0	0
1993	14	369	955	2,518	925	129	265	52	61	0	6	41	0
1994	748	1,258	3,313	2,739	1,605	449	36	195	88	70	0	32	65
1995	1,212	122	847	4,779	1,477	598	274	94	91	34	42	7	0
1996	31	339	839	2,048	5,527	880	753	148	0	56	15	0	0
1997	95	349	569	1,189	1,444	2,462	321	194	100	0	57	0	0
1998	65	211	1,929	1,808	1,418	1,022	1,371	225	116	6	0	0	0
1999	869	382	787	1,291	882	850	194	297	46	0	0	0	0

Table 11a. Total weight and number from ITQ surveys for cod in 124 repeated stations.

Year	Fundy		Inshore		Shelf		Total	
	weight	number	weight	number	weight	number	weight	number
1995	2038	1133	795	806	730	579	3563	2518
1996	2245	1333	411	329	886	769	3542	2431
1997	2365	1093	194	181	507	386	3066	1660
1998	2009	1392	340	251	480	320	2829	1963
1999	1587	1044	178	9260	394	480	2159	10784

Table 11b. Total weight and number from ITQ surveys for cod in 170 repeated stations.

Year	Fundy		Inshore		Shelf		Total	
	weight	number	weight	number	weight	number	weight	number
1995								
1996	2503	1419	426	355	1170	1018	4099	2792
1997	2465	1136	199	189	747	582	3411	1907
1998	2157	1445	365	269	628	457	3150	2171
1999	1668	1085	194	9289	537	661	2399	11035

Table 11c. ITQ survey indices for cod in Division 4X; 124 repeated stations.

Age	2	3	4	5	6	7	8	9	10	11
1995	733	1135	260	123	36	8	9	1	0	0
1996	738	692	626	71	23	4	0	3	0	1
1997	221	602	314	230	15	23	6	2	1	0
1998	806	562	236	85	94	13	6	0	0	0
1999	591	608	140	82	14	23	5	1	0	0

Table 12a. Statistical properties of estimates for population abundance and survey calibration constants for 4X cod using RV index (1983-1999) and ITQ index (1995-1999).

	Age	PAR. EST.	STD. ERR.	BIAS	REL. ERR.	REL. BIAS
Population Abundance	2	5825.048	3057.627	855.221	0.525	0.147
	3	5059.408	1981.626	417.558	0.392	0.083
	4	1839.286	702.203	131.284	0.382	0.071
	5	1608.013	605.907	108.125	0.377	0.067
	6	701.721	285.784	53.774	0.407	0.077
	7	1088.250	397.583	65.719	0.365	0.060
	8	159.521	59.469	9.472	0.373	0.059
	9	94.027	37.296	5.774	0.397	0.061
	10	37.638	16.593	2.573	0.441	0.068
RV survey	2	0.050	0.009	0.001	0.173	0.010
	3	0.353	0.062	0.004	0.175	0.011
	4	0.421	0.074	0.005	0.175	0.012
	5	0.480	0.082	0.005	0.170	0.011
	6	0.513	0.088	0.007	0.172	0.013
	7	0.690	0.119	0.010	0.172	0.014
	8	0.721	0.133	0.013	0.184	0.018
	9	0.712	0.133	0.013	0.186	0.019
	10	0.674	0.134	0.014	0.199	0.021
ITQ survey	2	0.097	0.034	0.005	0.346	0.047
	3	0.135	0.044	0.006	0.329	0.042
	4	0.100	0.033	0.004	0.327	0.044
	5	0.078	0.026	0.004	0.330	0.045
	6	0.052	0.017	0.003	0.338	0.050
	7	0.059	0.020	0.003	0.341	0.057
	8	0.069	0.027	0.006	0.388	0.081
	9	0.071	0.026	0.006	0.369	0.078

Mean Squared Residual = 0.468355

Table 12b. Statistical properties of estimates for population abundance and survey calibration constants for 4X cod using RV index (1983-1999), ages 2-7.

	Age	PAR. EST.	STD. ERR.	BIAS	REL. ERR.	REL. BIAS
Population Abundance	2	5804.728	2800.705	696.486	0.482	0.120
	3	5131.716	1837.603	334.026	0.358	0.065
	4	2524.712	841.245	131.193	0.333	0.052
	5	1917.662	640.043	93.032	0.334	0.049
	6	796.508	291.702	44.404	0.366	0.056
	7	1500.657	467.002	59.180	0.311	0.039
	8	446.150	153.006	19.797	0.343	0.044
	9	381.509	139.037	18.535	0.364	0.049
	10	142.628	59.130	8.932	0.415	0.063
RV Survey	2	0.048	0.006	0.000	0.121	0.004
	3	0.334	0.041	0.001	0.122	0.004
	4	0.388	0.047	0.002	0.122	0.005
	5	0.429	0.051	0.002	0.119	0.005
	6	0.438	0.053	0.004	0.122	0.008
	7	0.563	0.069	0.006	0.122	0.010

Mean Squared Residual = 0.218133

Table 13a. Estimated bias adjusted beginning of year population numbers (000's) for 4X cod using RV index (1983-1999) and ITQ index (1995-1999).

Age	1	2	3	4	5	6	7	8	9	10	11	1+	2+	3+	4+
1980	22,713	23,425	22,889	8,695	4,925	2,961	1,448	746	303	198	42	88,345	65,632	42,207	19,318
1981	26,209	18,595	18,394	13,216	4,971	2,456	1,403	789	378	167	108	86,686	60,477	41,882	23,488
1982	14,010	21,458	14,459	11,523	6,954	2,385	1,074	623	378	146	69	73,079	59,069	37,611	23,152
1983	13,883	11,471	16,733	9,225	5,433	2,925	1,131	527	259	179	43	61,809	47,926	36,455	19,722
1984	17,341	11,357	8,430	10,318	5,316	2,547	1,304	512	248	105	79	57,557	40,216	28,859	20,429
1985	9,448	14,166	8,429	4,713	5,654	2,615	1,218	652	260	147	42	47,344	37,896	23,730	15,301
1986	26,787	7,735	10,931	5,360	2,432	2,517	977	533	360	150	73	57,855	31,068	23,333	12,402
1987	18,359	21,931	6,104	6,413	2,618	1,088	1,156	439	255	211	76	58,650	40,291	18,360	12,256
1988	26,787	15,031	17,144	4,166	3,390	1,174	423	491	151	84	115	68,956	42,169	27,138	9,994
1989	8,999	21,931	11,936	10,856	1,880	1,380	374	188	232	47	22	57,845	48,846	26,915	14,979
1990	13,386	7,351	17,362	7,482	5,633	984	636	165	84	137	21	53,241	39,855	32,504	15,142
1991	14,210	10,959	5,885	11,620	3,583	2,405	353	272	65	33	78	49,463	35,253	24,294	18,409
1992	9,759	11,632	8,611	3,421	4,921	1,323	737	92	80	24	13	40,613	30,854	19,222	10,611
1993	17,721	7,990	8,816	3,913	1,082	1,093	295	148	19	21	6	41,104	23,383	15,393	6,577
1994	8,537	14,508	5,718	4,068	1,358	296	295	75	39	3	5	34,902	26,365	11,857	6,139
1995	8,074	6,989	11,432	2,614	1,319	309	67	78	23	16	2	30,923	22,849	15,860	4,428
1996	5,436	6,611	5,596	7,395	1,163	559	135	30	27	9	8	26,969	21,533	14,922	9,326
1997	8,539	4,450	5,366	3,767	3,686	552	266	85	10	15	5	26,741	18,202	13,752	8,386
1998	6,714	6,991	3,587	3,354	1,653	1,925	268	143	54	6	7	24,702	17,988	10,997	7,410
1999	11,052	5,497	5,501	2,121	1,811	793	1,175	170	99	39	3	28,261	17,209	11,712	6,211

Table 13b. Estimated bias adjusted beginning of year population numbers (000's) for 4X cod using Rvindex (1983-1999), ages 2-7.

Age	1	2	3	4	5	6	7	8	9	10	11	1+	2+	3+	4+
1980	22,713	23,425	22,890	8,695	4,925	2,961	1,448	746	303	198	42	88,343	65,631	42,206	19,316
1981	26,213	18,596	18,394	13,216	4,972	2,456	1,403	789	378	167	108	86,691	60,477	41,882	23,488
1982	14,011	21,461	14,459	11,523	6,954	2,385	1,074	623	378	146	69	73,084	59,073	37,611	23,152
1983	13,883	11,472	16,736	9,225	5,433	2,925	1,131	527	259	179	43	61,812	47,929	36,457	19,721
1984	17,345	11,357	8,431	10,320	5,316	2,547	1,304	512	248	105	79	57,565	40,220	28,862	20,431
1985	9,455	14,169	8,429	4,714	5,656	2,615	1,218	652	261	147	42	47,358	37,904	23,734	15,306
1986	26,840	7,740	10,934	5,360	2,432	2,519	978	533	360	150	73	57,919	31,078	23,338	12,404
1987	18,393	21,975	6,108	6,416	2,618	1,089	1,157	439	255	211	76	58,736	40,343	18,368	12,260
1988	26,799	15,059	17,180	4,170	3,392	1,174	424	492	151	84	115	69,039	42,240	27,181	10,001
1989	9,004	21,941	11,958	10,885	1,882	1,382	374	188	233	47	22	57,916	48,911	26,970	15,012
1990	14,046	7,356	17,370	7,500	5,657	987	637	165	85	137	21	53,961	39,915	32,559	15,189
1991	15,715	11,500	5,888	11,627	3,598	2,424	355	273	65	34	78	51,558	35,843	24,343	18,454
1992	10,998	12,865	9,053	3,424	4,927	1,336	753	94	81	24	13	43,568	32,569	19,705	10,651
1993	19,258	9,005	9,824	4,275	1,085	1,098	306	161	20	22	6	45,060	25,802	16,797	6,973
1994	8,850	15,767	6,548	4,893	1,655	298	298	83	50	4	5	38,453	29,603	13,836	7,287
1995	8,873	7,246	12,463	3,293	1,995	551	68	81	30	24	3	34,627	25,754	18,508	6,046
1996	6,816	7,265	5,806	8,238	1,720	1,112	334	31	29	15	15	31,381	24,565	17,301	11,494
1997	8,796	5,581	5,901	3,938	4,377	1,008	719	247	11	17	10	30,606	21,809	16,229	10,328
1998	6,901	7,202	4,512	3,792	1,794	2,490	641	514	188	7	9	28,050	21,148	13,947	9,434
1999	9,947	5,650	5,673	2,879	2,170	908	1,638	475	403	148	4	29,894	19,948	14,298	8,625

Table 14a. Estimated population biomass (000t) at the beginning of year for 4X cod using the RV index (1983-1999) and the ITQ index (1995-1999).

Age	1	2	3	4	5	6	7	8	9	10	11	1+	2+	3+	4+
1980	10,448	16,632	25,407	14,695	11,574	9,890	6,675	4,580	2,654	2,323	570	105,447	94,999	78,367	52,960
1981	12,056	13,202	20,417	22,335	11,682	8,203	6,468	4,844	3,311	1,959	1,464	105,943	93,887	80,684	60,267
1982	6,445	15,235	16,049	19,474	16,342	7,966	4,951	3,825	3,311	1,713	936	96,247	89,802	74,567	58,518
1983	6,386	8,144	18,574	15,590	12,768	9,770	5,214	3,236	2,269	2,100	583	84,633	78,247	70,102	51,529
1984	7,977	8,063	9,357	17,437	12,493	8,507	6,011	3,144	2,172	1,232	1,071	77,465	69,488	61,425	52,067
1985	4,346	10,058	9,356	7,965	13,287	8,734	5,615	4,003	2,278	1,724	570	67,936	63,590	53,532	44,176
1986	12,322	5,492	12,133	9,058	5,715	8,407	4,504	3,273	3,154	1,760	990	66,807	54,485	48,993	36,860
1987	8,445	15,571	6,775	10,838	6,152	3,634	5,329	2,695	2,234	2,475	1,031	65,180	56,735	41,164	34,388
1988	12,322	10,672	19,030	7,041	7,967	3,921	1,950	3,015	1,323	985	1,559	69,784	57,462	46,790	27,760
1989	4,140	15,571	13,249	18,347	4,418	4,609	1,724	1,154	2,032	551	298	66,094	61,954	46,383	33,134
1990	6,158	5,219	19,272	12,645	13,238	3,287	2,932	1,013	736	1,607	285	66,390	60,232	55,013	35,741
1991	3,979	7,956	6,591	20,997	9,638	8,843	1,626	1,801	529	407	1,146	63,514	59,535	51,579	44,988
1992	2,733	8,445	9,644	6,182	13,237	4,865	3,395	609	651	296	191	50,248	47,516	39,071	29,427
1993	4,962	5,801	9,874	7,071	2,911	4,019	1,359	980	155	259	88	37,478	32,516	26,715	16,841
1994	2,390	10,533	6,404	7,351	3,653	1,088	1,359	497	317	37	73	33,703	31,313	20,780	14,376
1995	2,261	5,074	12,804	4,723	3,548	1,136	309	517	187	197	29	30,786	28,525	23,451	10,647
1996	1,522	4,800	6,268	13,363	3,128	2,055	622	199	220	111	117	32,405	30,883	26,083	19,816
1997	2,391	3,231	6,010	6,807	9,915	2,030	1,225	563	81	185	73	32,512	30,121	26,890	20,880
1998	1,880	5,075	4,017	6,061	4,447	7,078	1,235	947	439	74	103	31,356	29,476	24,401	20,383
1999	3,095	3,991	6,161	3,833	4,872	2,916	5,413	1,126	806	481	44	32,737	29,642	25,651	19,490

Table 14b. Estimated population biomass (000 t) at the beginning of year for 4X cod using the RV index (1983-1999), ages 2-7.

Age	1	2	3	4	5	6	7	8	9	10	11	1+	2+	3+	4+
1980	10,448	16,632	25,407	14,694	11,573	9,891	6,675	4,577	2,651	2,320	563	105,431	94,984	78,352	52,944
1981	12,058	13,203	20,418	22,336	11,683	8,204	6,466	4,842	3,311	1,954	1,462	105,936	93,878	80,675	60,257
1982	6,445	15,238	16,049	19,474	16,341	7,966	4,953	3,823	3,309	1,717	939	96,255	89,810	74,572	58,523
1983	6,386	8,145	18,577	15,590	12,767	9,769	5,216	3,238	2,266	2,095	582	84,630	78,244	70,099	51,522
1984	7,979	8,064	9,358	17,441	12,493	8,507	6,012	3,146	2,170	1,227	1,075	77,472	69,493	61,429	52,071
1985	4,349	10,060	9,356	7,966	13,292	8,733	5,616	4,005	2,282	1,728	574	67,963	63,614	53,553	44,197
1986	12,347	5,496	12,137	9,058	5,716	8,413	4,506	3,270	3,152	1,759	984	66,838	54,491	48,996	36,859
1987	8,461	15,602	6,780	10,842	6,152	3,637	5,334	2,693	2,231	2,479	1,029	65,241	56,780	41,178	34,398
1988	12,328	10,692	19,070	7,047	7,972	3,920	1,953	3,023	1,321	984	1,556	69,865	57,537	46,845	27,776
1989	4,142	15,578	13,274	18,396	4,424	4,614	1,723	1,154	2,037	547	298	66,187	62,045	46,467	33,193
1990	6,461	5,223	19,281	12,675	13,294	3,295	2,939	1,013	741	1,612	285	66,819	60,357	55,135	35,854
1991	4,400	8,349	6,595	21,010	9,679	8,915	1,637	1,807	530	414	1,147	64,483	60,083	51,734	45,139
1992	3,079	9,340	10,140	6,187	13,253	4,911	3,467	620	661	302	193	52,154	49,074	39,734	29,595
1993	5,392	6,537	11,003	7,726	2,918	4,036	1,408	1,066	165	269	93	40,614	35,222	28,684	17,681
1994	2,478	11,447	7,334	8,842	4,452	1,096	1,375	549	409	52	77	38,111	35,633	24,186	16,852
1995	2,484	5,260	13,958	5,951	5,366	2,027	315	535	241	301	44	36,483	33,999	28,738	14,780
1996	1,908	5,274	6,503	14,887	4,627	4,090	1,538	206	240	179	221	39,672	37,763	32,489	25,986
1997	2,463	4,051	6,609	7,117	11,775	3,705	3,313	1,638	91	208	147	41,117	38,654	34,603	27,993
1998	1,932	5,228	5,054	6,852	4,825	9,158	2,954	3,401	1,527	88	126	41,146	39,213	33,985	28,931
1999	2,785	4,102	6,353	5,202	5,838	3,340	7,545	3,145	3,277	1,825	62	43,474	40,689	36,587	30,234

Table 15a. Estimated bias adjusted fishing mortality (F) and exploitation rate for 4X cod using the RV index (1983-1999) and ITQ index (1995-1999).

Age	1	2	3	4	5	6	7	8	9	10	11	Avg F*	% exploit
1980	0.00	0.04	0.36	0.39	0.49	0.57	0.44	0.41	0.50	0.49	0.38	0.43	31.80
1981	0.00	0.05	0.26	0.44	0.57	0.59	0.60	0.56	0.65	0.62	0.51	0.49	35.51
1982	0 00	0.05	0.25	0.54	0.64	0.56	0.49	0.67	0.59	1.11	1.26	0.58	40.48
1983	0.00	0.11	0.28	0.36	0.60	0.63	0.63	0.52	0.67	0.50	2.08	0.46	33.63
1984	0.00	0.10	0.37	0.38	0.46	0.51	0.46	0.50	0.31	0.71	0.65	0.45	33.28
1985	0.00	0.06	0.27	0.49	0.64	0.62	0.74	0.40	0.35	0.46	0.50	0.59	40.67
1986	0.00	0.04	0.31	0.50	0.62	0.60	0.56	0.68	0.44	0.56	0.54	0.56	38.99
1987	0.00	0.05	0.20	0.44	0.61	0.85	0.66	0.75	0.87	0.57	0.51	0.52	37.17
1988	0.00	0.03	0.27	0.67	0.74	0.89	0.77	0.63	0.90	0.98	0.35	0.67	44.90
1989	0.00	0.03	0.26	0.42	0.43	0.47	0.41	0.49	0.32	0.52	0.77	0.47	34.23
1990	0.00	0.03	0.21	0.55	0.64	0.87	0.64	0.72	0.76	0.40	1.18	0.60	41.36
1991	0.00	0.04	0.32	0.63	0.86	1.08	1.33	1.17	0.83	1.19	0.58	0.73	47.61
1992	0.00	0.08	0.63	0.97	1.29	1.23	1.22	1.21	1.01	0.68	1.32	1.18	63.98
1993	0.00	0.13	0.59	0.89	1.01	1.09	1.16	1.11	1.56	1.26	1.93	0.95	56.40
1994	0.00	0.04	0.52	0.86	1.29	1.23	1.16	1.02	0.76	0.24	0.54	1.02	58.99
1995	0.00	0.02	0.22	0.60	0.62	0.57	0.51	0.86	0.84	0.45	0.43	0.63	42.59
1996	0.00	0.01	0.20	0.49	0.51	0.51	0.27	0.79	0.26	0.30	0.14	0.50	36.02
1997	0.00	0.02	0.28	0.63	0.49	0.56	0.43	0.26	0.27	0.59	0.30	0.53	37.57
1998	0.00	0.04	0.31	0.39	0.48	0.28	0.24	0.15	0.13	0.36	0.55	0.40	30.12
1999**	0.00	0.00	0.23	0.38	0.29	0.25	0.11	0.05	0.05	0.01	0.21		

*Fully recruited F, calculated for ages 4-7

**Annualized F for Jan-Jul 1, 1999

Table 15b. Estimated bias adjusted fishing mortality (F) and exploitation rate for 4X cod using the RV index (1983-1999), ages 2-7.

Age	1	2	3	4	5	6	7	8	9	10	11	Avg F	% exploit
1980	0.00	0.04	0.35	0.36	0.50	0.55	0.41	0.48	0.40	0.41	0.66	0.43	31.80
1981	0.00	0.05	0.27	0.44	0.53	0.63	0.61	0.54	0.75	0.68	0.50	0.49	35.51
1982	0.00	0.05	0.25	0.55	0.67	0.55	0.51	0.68	0.55	1.03	1.05	0.58	40.48
1983	0.00	0.11	0.28	0.35	0.56	0.61	0.59	0.56	0.71	0.61	2.42	0.46	33.63
1984	0.00	0.10	0.38	0.40	0.51	0.54	0.49	0.48	0.32	0.70	0.52	0.45	33.27
1985	0.00	0.06	0.25	0.46	0.61	0.78	0.63	0.40	0.35	0.51	0.62	0.59	40.67
1986	0.00	0.04	0.33	0.52	0.60	0.58	0.60	0.54	0.33	0.48	0.43	0.56	38.99
1987	0.00	0.05	0.18	0.44	0.60	0.74	0.65	0.87	0.91	0.41	0.65	0.52	37.15
1988	0.00	0.03	0.26	0.60	0.70	0.94	0.61	0.55	0.97	1.14	0.32	0.67	44.89
1989	0.00	0.03	0.27	0.45	0.45	0.57	0.62	0.60	0.33	0.60	0.66	0.47	34.14
1990	0.00	0.02	0.20	0.53	0.65	0.82	0.65	0.73	0.72	0.37	1.31	0.60	41.23
1991	0.00	0.04	0.34	0.66	0.79	0.97	1.13	1.01	0.78	0.74	0.51	0.73	47.49
1992	0.00	0.07	0.55	0.95	1.30	1.27	1.34	1.33	1.12	1.15	1.23	1.17	63.74
1993	0.00	0.12	0.50	0.75	1.09	1.10	1.11	0.96	1.37	1.23	1.96	0.86	53.17
1994	0.00	0.04	0.49	0.70	0.90	1.27	1.11	0.83	0.52	0.15	0.50	0.77	49.50
1995	0.00	0.02	0.21	0.45	0.38	0.30	0.59	0.81	0.51	0.29	0.29	0.41	30.94
1996	0.00	0.01	0.19	0.43	0.33	0.24	0.10	0.82	0.36	0.18	0.07	0.39	29.17
1997	0.00	0.01	0.24	0.59	0.36	0.25	0.14	0.08	0.25	0.47	0.15	0.41	30.89
1998	0.00	0.04	0.25	0.36	0.48	0.22	0.10	0.04	0.04	0.34	0.42	0.32	24.84
1999 *	0.00	0.00	0.14	0.17	0.15	0.18	0.06	0.02	0.01	0.00	0.10		

* Annualized F for Jan - Jul 1999

Table 16a. Annual partial recruitment values and average partial recruitment values for cod in Division 4X using the RV survey index (1983-1999) and the ITQ survey index (1995-1999).

Age	2	3	4	5	6	7	8	9	10	11
1988	0.042	0.381	0.949	1.051	1.267	1.094	0.886	1.276	1.392	0.498
1989	0.082	0.620	0.992	1.008	1.112	0.975	1.159	0.767	1.232	1.815
1990	0.042	0.356	0.924	1.076	1.473	1.073	1.210	1.277	0.668	1.989
1991	0.051	0.426	0.847	1.153	1.443	1.774	1.560	1.104	1.592	0.779
1992	0.069	0.555	0.858	1.142	1.093	1.083	1.072	0.897	0.601	1.170
1993	0.141	0.622	0.935	1.065	1.148	1.215	1.169	1.644	1.321	2.026
1994	0.035	0.487	0.799	1.201	1.148	1.084	0.952	0.707	0.222	0.502
1995	0.036	0.366	0.985	1.015	0.935	0.838	1.402	1.369	0.739	0.701
1996	0.017	0.403	0.978	1.022	1.024	0.537	1.576	0.525	0.607	0.271
1997	0.028	0.498	1.124	0.876	0.985	0.756	0.456	0.486	1.051	0.535
1998	0.092	0.728	0.894	1.106	0.656	0.566	0.350	0.303	0.833	1.272
1999	0.007	0.674	1.140	0.860	0.746	0.320	0.163	0.151	0.019	0.641
PR Avg 95-99	0.036	0.534	1.024	0.976	0.869	0.603	0.789	0.567	0.650	0.684
PR Avg 88-99	0.054	0.510	0.952	1.048	1.086	0.943	0.996	0.875	0.856	1.017

Table 16b. Annual partial recruitment and average partial recruitment values for cod in Division 4X using the RV survey index (1983-1999), ages 2-7.

Age	2	3	4	5	6	7	8	9	10	11
1988	0.047	0.396	0.920	1.080	1.460	0.946	0.851	1.507	1.759	0.501
1989	0.075	0.592	1.009	0.991	1.274	1.371	1.330	0.724	1.326	1.467
1990	0.038	0.341	0.905	1.095	1.390	1.097	1.237	1.226	0.618	2.225
1991	0.054	0.472	0.909	1.091	1.338	1.563	1.397	1.073	1.017	0.708
1992	0.062	0.489	0.844	1.156	1.133	1.193	1.184	0.991	1.022	1.133
1993	0.129	0.540	0.814	1.186	1.198	1.201	1.048	1.485	1.332	2.132
1994	0.044	0.610	0.873	1.127	1.594	1.387	1.038	0.654	0.183	0.625
1995	0.051	0.513	1.078	0.922	0.723	1.414	1.939	1.227	0.684	0.692
1996	0.021	0.491	1.127	0.873	0.615	0.260	2.130	0.935	0.457	0.177
1997	0.026	0.510	1.234	0.766	0.530	0.288	0.161	0.525	0.998	0.310
1998	0.092	0.595	0.854	1.146	0.523	0.239	0.103	0.091	0.801	1.009
1999	0.011	0.855	1.070	0.930	1.124	0.350	0.100	0.047	0.011	0.619
PR Avg 95-99	0.040	0.593	1.073	0.927	0.703	0.510	0.887	0.565	0.590	0.561
PR Avg 88-99	0.054	0.534	0.970	1.030	1.075	0.942	1.043	0.874	0.851	0.967

Table 17. Summary of Stock Status Attributes.

Attribute	Recent Trends	Current Status
Biomass SPA ages 4+ (1980-1999)	Unchanged	Low
Biomass RV Kg/tow (1970-1999)	Decreasing	Lowest observed
Recruitment SPA age 1 (1980-1998)	Unchanged	Low
Recruitment RV age 2 (1983-1999)	Unchanged	Low
Exploitation SPA age 4-7 (1980-1999)	Decreasing	Lowest observed, but above $F_{0.1}$
Total Mortality RV ages 4+ (1983-1999)	Increasing	Above average
Condition	Unchanged	High
Resource Concentration	Unchanged	More concentrated than average
Geographic Distribution	Unchanged	Average
Mean length age 4 (1970-1999)	Unchanged	Average

Table 18a. Projections for cod in Division 4X using the RV survey index (1983-1999) and the ITQ survey index (1995-1999).

	Beg.-yr. Wt.			Mid-yr. Wt.		Catch Biomass		Catch Numbers		F		Population Numbers			Population Biomass		
Age	1999.5	2000*	2001	1999.5	2000*	1999.5	2000*	1999.5	2000*	1999.5	2000*	1999.5	2000*	2001	1999.5	2000*	2001
1	0.38	0.28	0.28	0.48	0.38	0	0	0	0	0.000	0.000	10,000	9,000	9,000	3,800	2,520	2,520
2	0.89	0.73	0.73	0.91	0.89	125	69	138	76	0.040	0.010	4,970	8,607	7,369	4,423	6,283	5,379
3	1.39	1.12	1.12	1.45	1.39	880	422	607	303	0.202	0.084	4,642	4,150	6,977	6,452	4,648	7,814
4	2.07	1.81	1.81	2.21	2.07	798	911	361	440	0.343	0.152	1,706	3,434	3,124	3,536	6,216	5,654
5	3.09	2.69	2.69	3.17	3.09	1,158	579	365	187	0.404	0.200	1,500	1,137	2,415	4,635	3,057	6,497
6	4.20	3.68	3.68	4.31	4.2	680	660	158	157	0.404	0.200	648	954	762	2,721	3,510	2,804
7	5.58	4.61	4.61	5.87	5.58	1,462	379	249	66	0.404	0.200	1,023	412	639	5,706	1,899	2,947
8	7.45	6.62	6.62	7.46	7.45	273	798	37	107	0.404	0.200	150	650	276	1,118	4,304	1,828
9	10.52	8.14	8.14	9.91	10.52	213	165	21	16	0.404	0.200	88	95	436	928	777	3,548
10	12.60	12.34	12.34	11.95	12.6	102	117	9	9	0.404	0.200	35	56	64	442	692	789
11	15.58	14.69	14.69	14.09	15.58	10	57	1	4	0.404	0.200	3	22	38	46	326	553
1+						5,701	4,157								33,807	34,234	40,333
2+						5,701	4,157								30,007	31,714	37,813
3+						5,576	4,088								25,584	25,431	32,434
4+						4,696	3,666								19,132	20,783	24,620

*fishing year beginning April 1, 2000.

Table 18b. Projections for cod in Division 4X using the RV survey index (1983-1999), ages 2-7.

	Beg.-yr. Wt.			Mid-yr. Wt.		Catch Biomass		Catch Numbers		F		Population Numbers			Population Biomass		
Age	1999.5	2000*	2001	1999.5	2000*	1999.5	2000*	1999.5	2000*	1999.5	2000*	1999.5	2000*	2001	1999.5	2000*	2001
1	0.38	0.28	0.28	0.48	0.38	0	0	0	0	0.000	0.000	9,000	9,000	9,000	3,420	2,520	2,520
2	0.89	0.73	0.73	0.91	0.89	83	50	91	56	0.013	0.008	5,108	7,746	7,369	4,546	5,655	5,379
3	1.39	1.12	1.12	1.45	1.39	600	614	414	442	0.191	0.119	4,798	4,312	6,279	6,669	4,829	7,033
4	2.07	1.81	1.81	2.21	2.07	751	1,301	340	628	0.346	0.215	2,394	3,746	3,246	4,955	6,781	5,875
5	3.09	2.69	2.69	3.17	3.09	952	756	300	245	0.299	0.185	1,825	1,746	2,635	5,638	4,697	7,088
6	4.20	3.68	3.68	4.31	4.2	534	628	268	150	0.227	0.141	752	1,293	1,170	3,159	4,757	4,307
7	5.58	4.61	4.61	5.87	5.58	1,393	268	237	48	0.164	0.102	1,441	533	867	8,043	2,456	3,995
8	7.45	6.62	6.62	7.46	7.45	524	1,207	70	162	0.286	0.177	426	1,021	357	3,176	6,761	2,365
9	10.52	8.14	8.14	9.91	10.52	592	302	60	29	0.182	0.113	363	302	685	3,818	2,459	5,572
10	12.60	12.34	12.34	11.95	12.6	263	347	22	28	0.190	0.118	134	257	202	1,685	3,173	2,499
11	15.58	14.69	14.69	14.09	15.58	8	150	1	10	0.181	0.112	4	95	172	56	1,391	2,532
1+						5,700	5,623								45,165	45,479	49,165
2+						5,700	5,623								41,745	42,959	46,645
3+						5,617	5,573								37,199	37,304	41,266
4+						5,017	4,959								30,530	32,475	34,233

*fishing year beginning April 1, 2000.

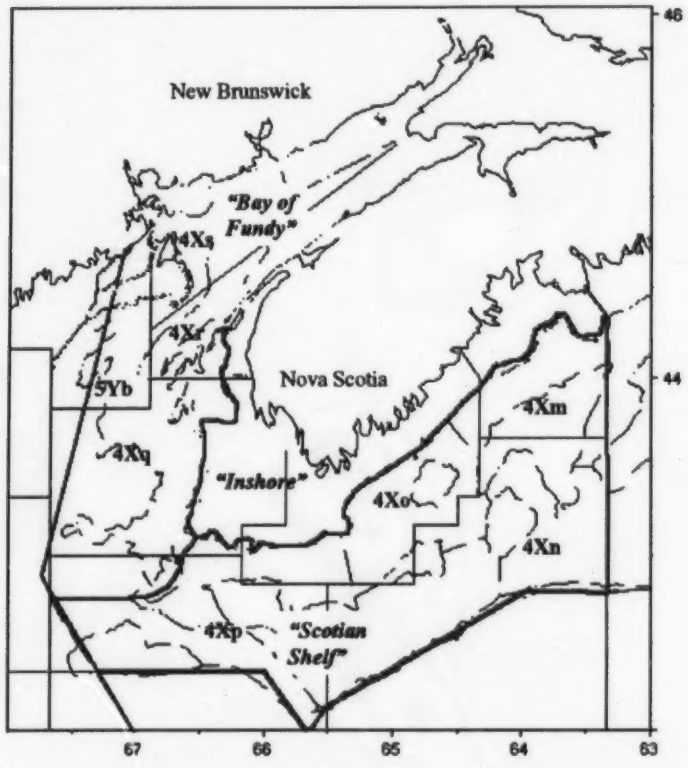

Fig. 1. Canadian Statistical unit areas in NAFO Divisions 4X and 5Y, showing "Bay of Fundy", "Inshore" and "Scotian Shelf" regions as used in the analysis of the ITQ survey data.

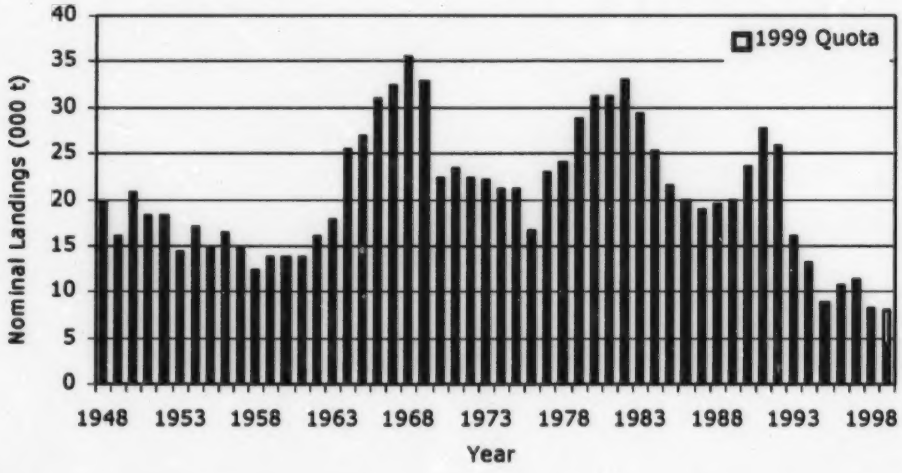

Fig. 2. Nominal landings of cod in Division 4X including catches by Canada in Division 5Y. For 1999, quota and mid-year landings are shown.

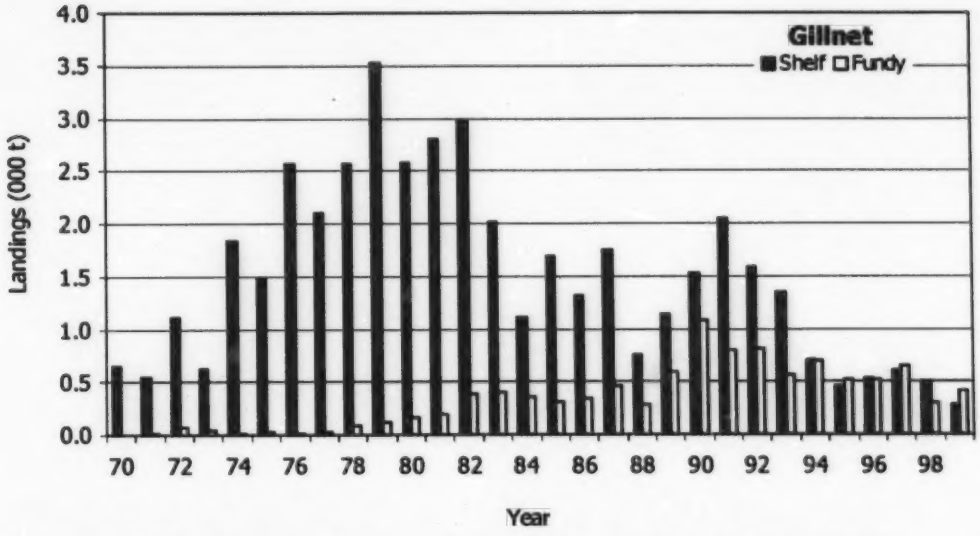

Fig. 3a. Annual landings by gill net vessels in the Bay of Fundy and Scotian Shelf.

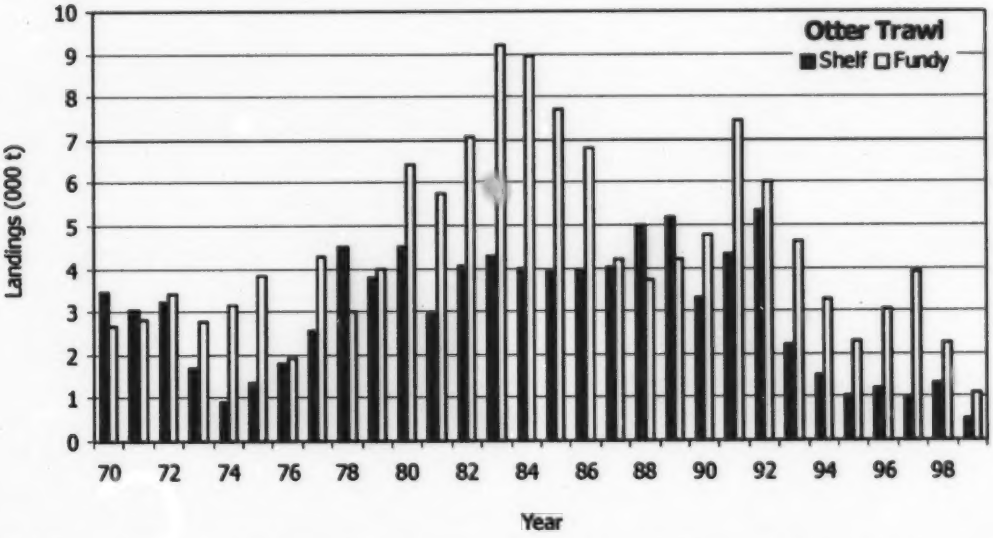

Fig. 3b. Annual landings by otter trawl vessels in the Bay of Fundy and Scotian Shelf.

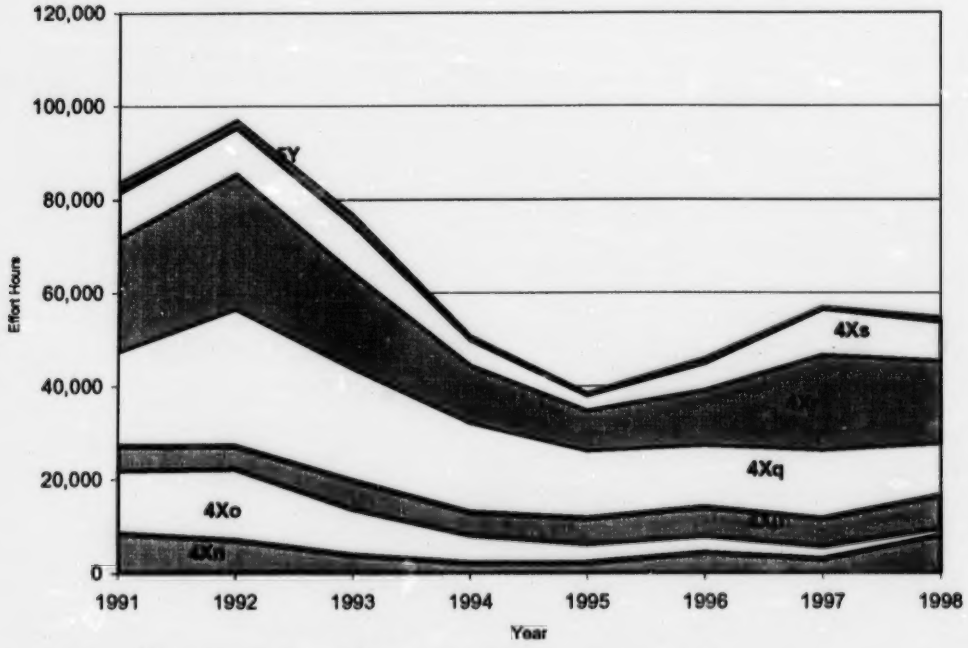

Fig. 4a. Fishing effort expended by the OT TC 1-3 fleet in 4X where main species was cod, hadock, pollock, or white hake; TVRP effort excluded.

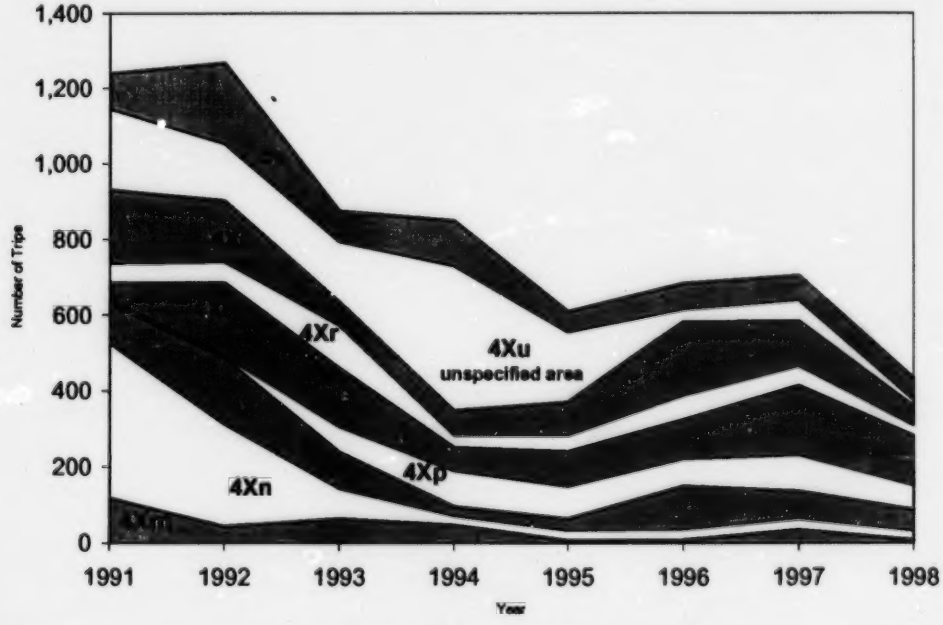

Fig. 4b. Fishing effort for gill net (TC 2+) fishing vessels by unit area in 4X.

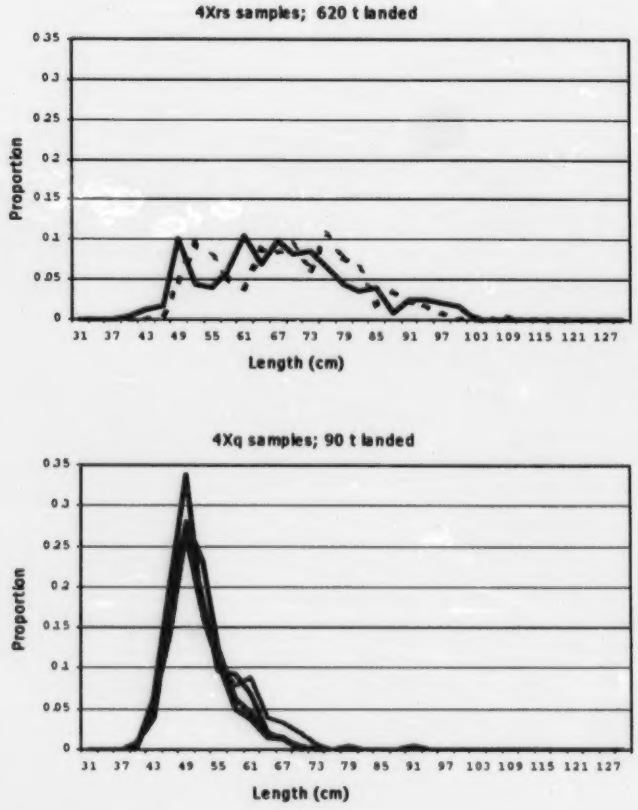

Fig. 5. A comparison of individual commercial otter trawl samples taken in the Bay of Fundy from unit areas 4Xrs and 4Xq in 1998.

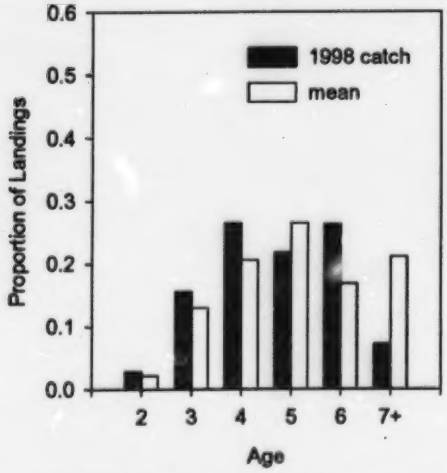

Fig. 6. Division 4X cod catch (t) at age for 1998 compared to the 1980-96 mean.

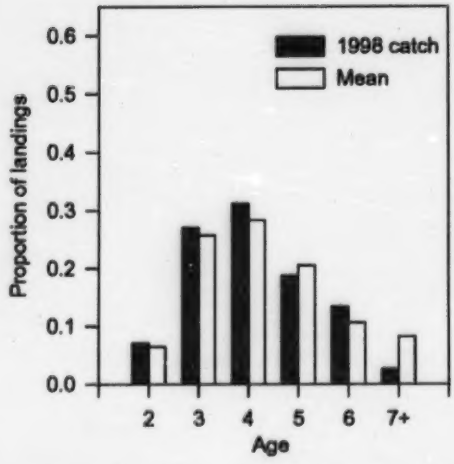

Fig. 7. 4X cod catch at age (in numbers) for 1998 compared to the mean for 1980-96.

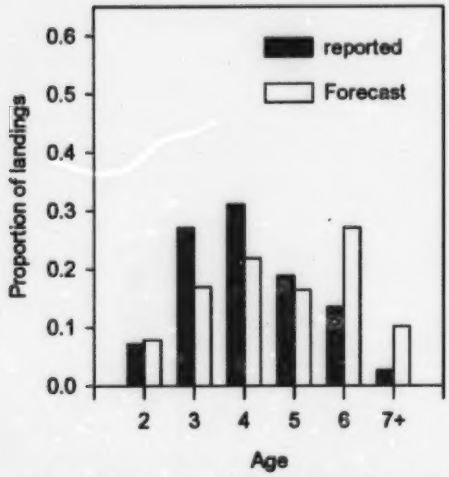

Fig. 8. Reported and forecast landings of cod in Division 4X for 1998 proportioned by age.

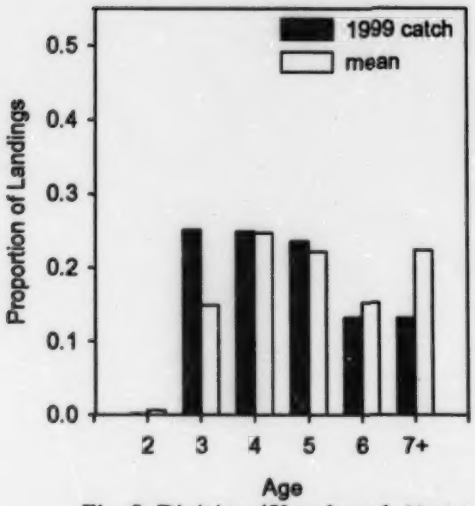

Fig. 9. Division 4X cod catch (t) at age for 1999 compared to the 1980-96 mean (Jan.-July).

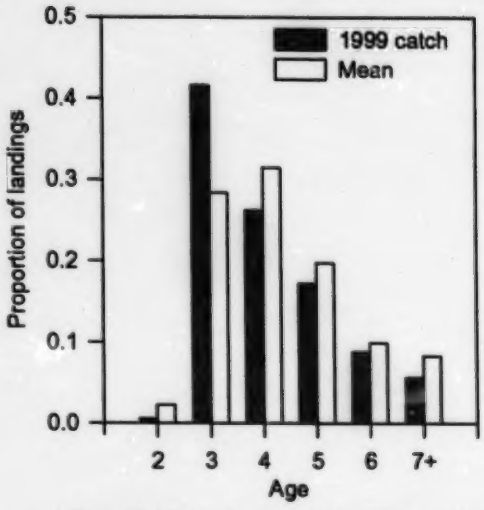

Fig. 10. 4X cod catch at age (in numbers) for 1999 compared to the mean for 1980 -1996 (January - July).

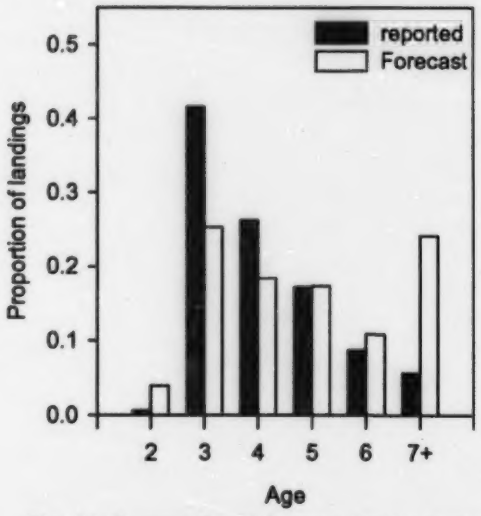

Fig. 11. Reported and forecast landings at age of cod in Division 4X for 1999 (Jan. - July).

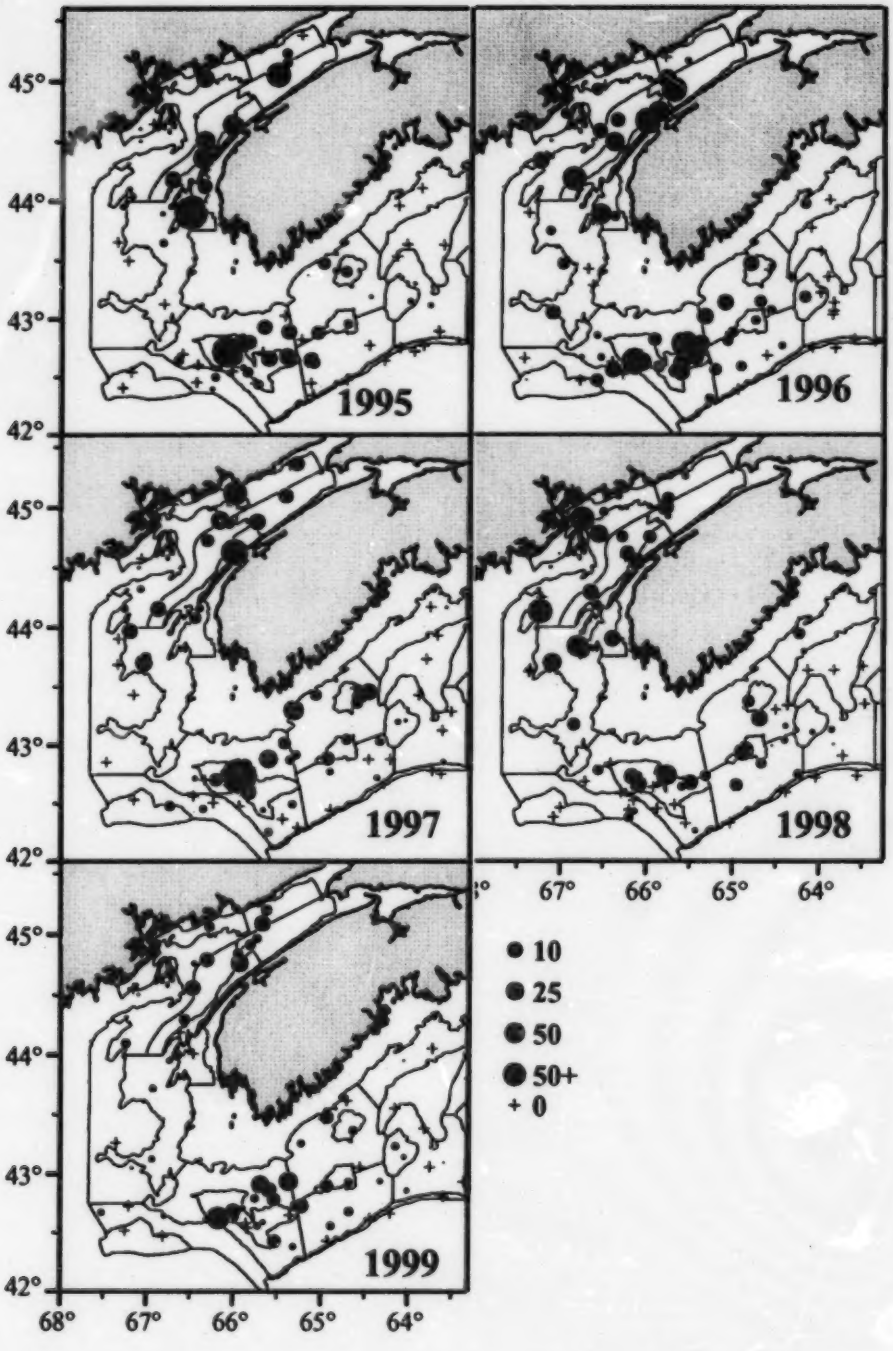

Fig. 12. Summer RV groundfish survey 4X cod catches (Kg/tow).

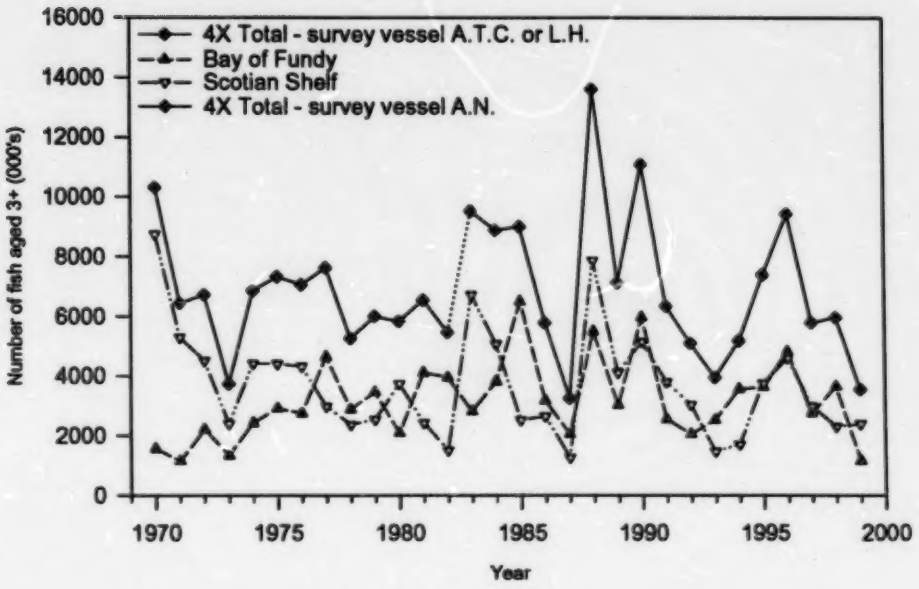

Fig. 13a. Summer groundfish survey indices for 4X cod by region.

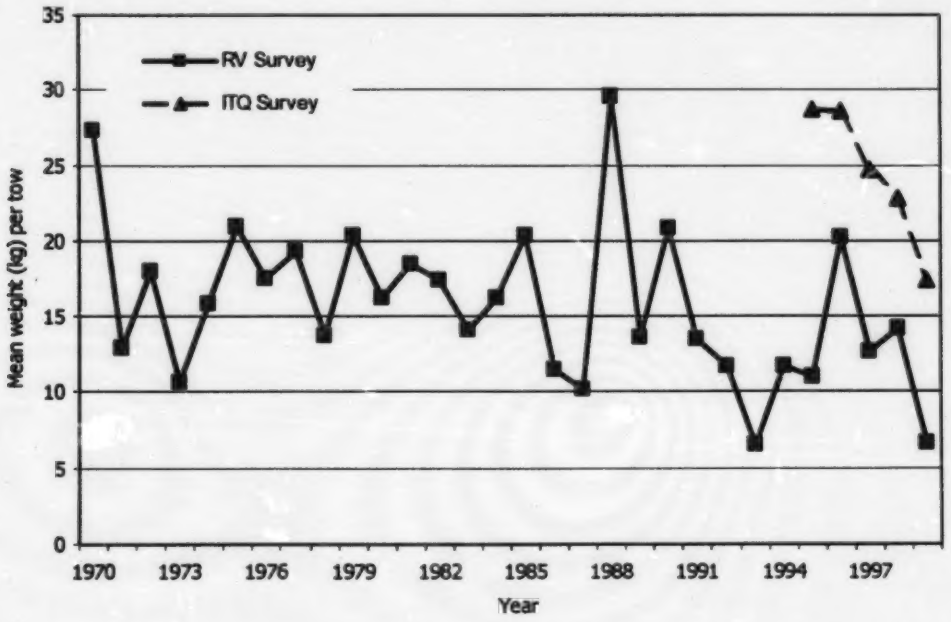

Fig. 13b. Mean weight (kg) per tow from the RV and ITQ surveys.

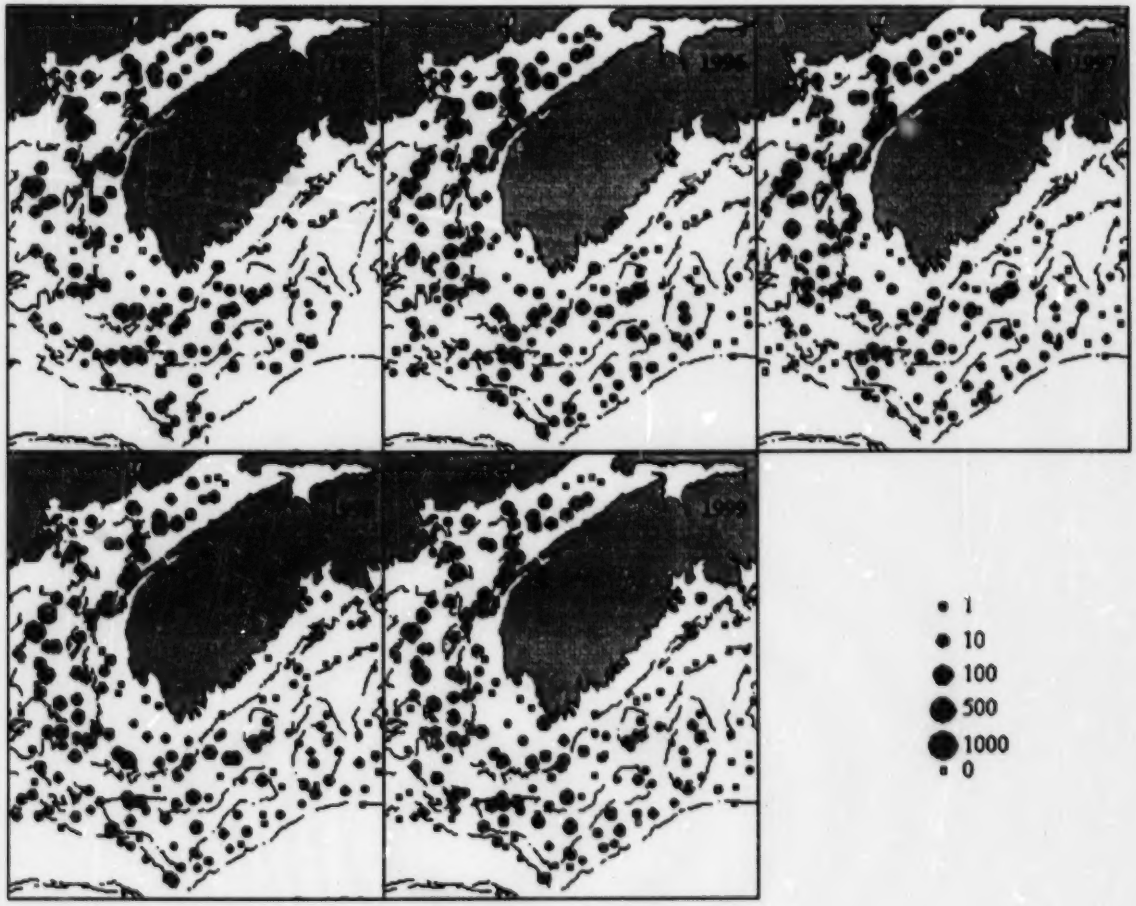

Fig. 14. Summer ITQ groundfish survey 4X cod catches (Kg/tow).

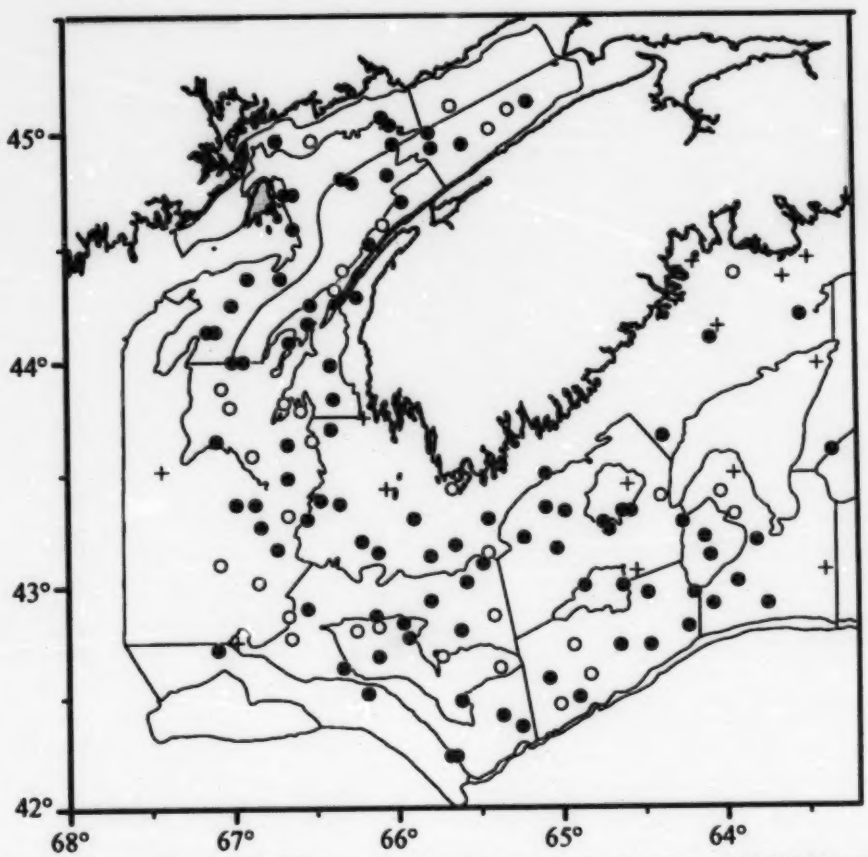

Fig. 15. A comparison of ITQ survey cod catches at repeated stations for 1999 versus the five year average from 1995 to 1999.

• Stations where 1999 value < average
+ Stations where 1999 value = average
o Stations where 1999 value > average

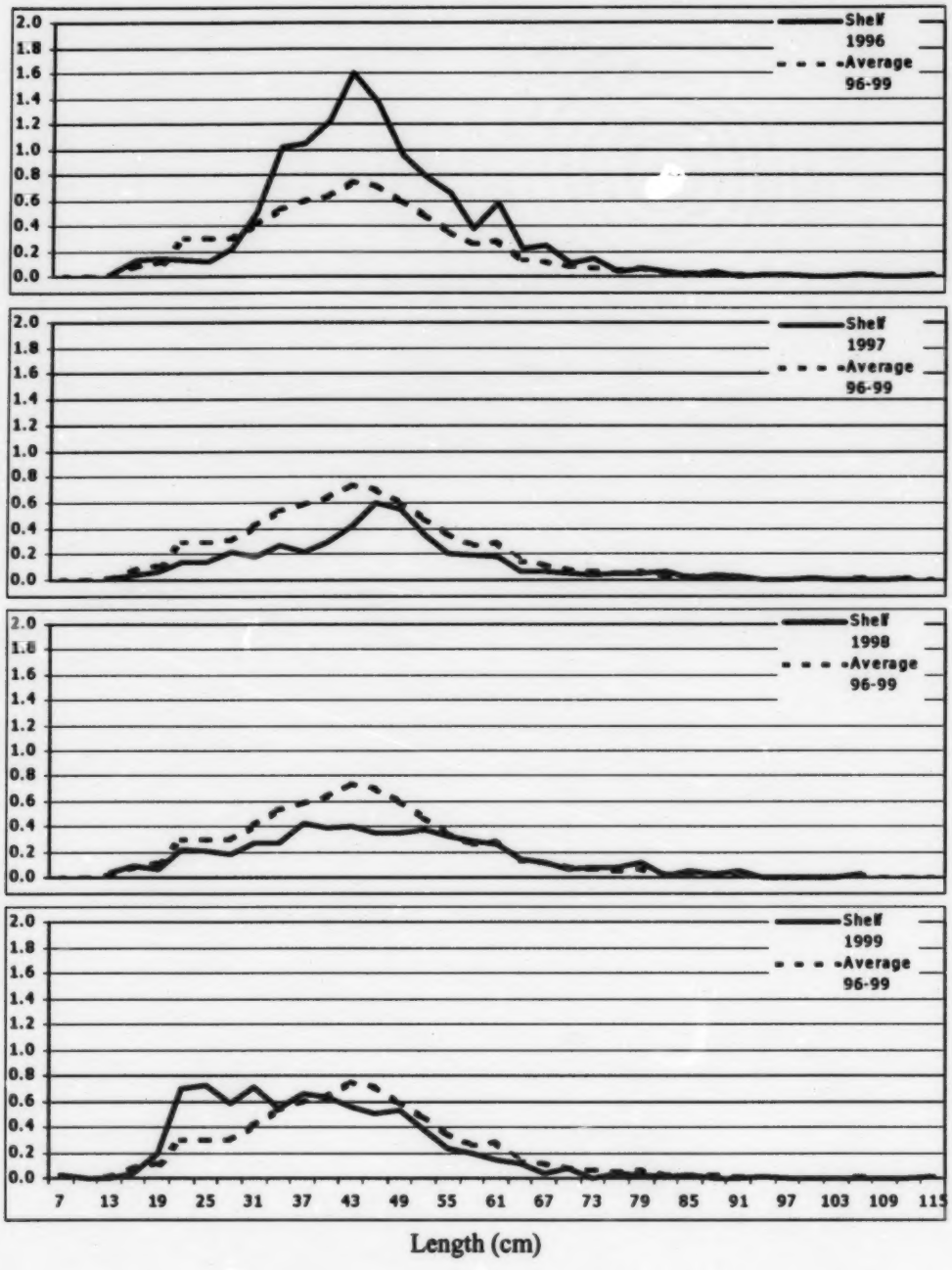

Fig. 16a. Scotian Shelf length frequencies and mean length at age from the ITQ surveys conducted in Division 4X; common sets from 1995-1999, n=124.

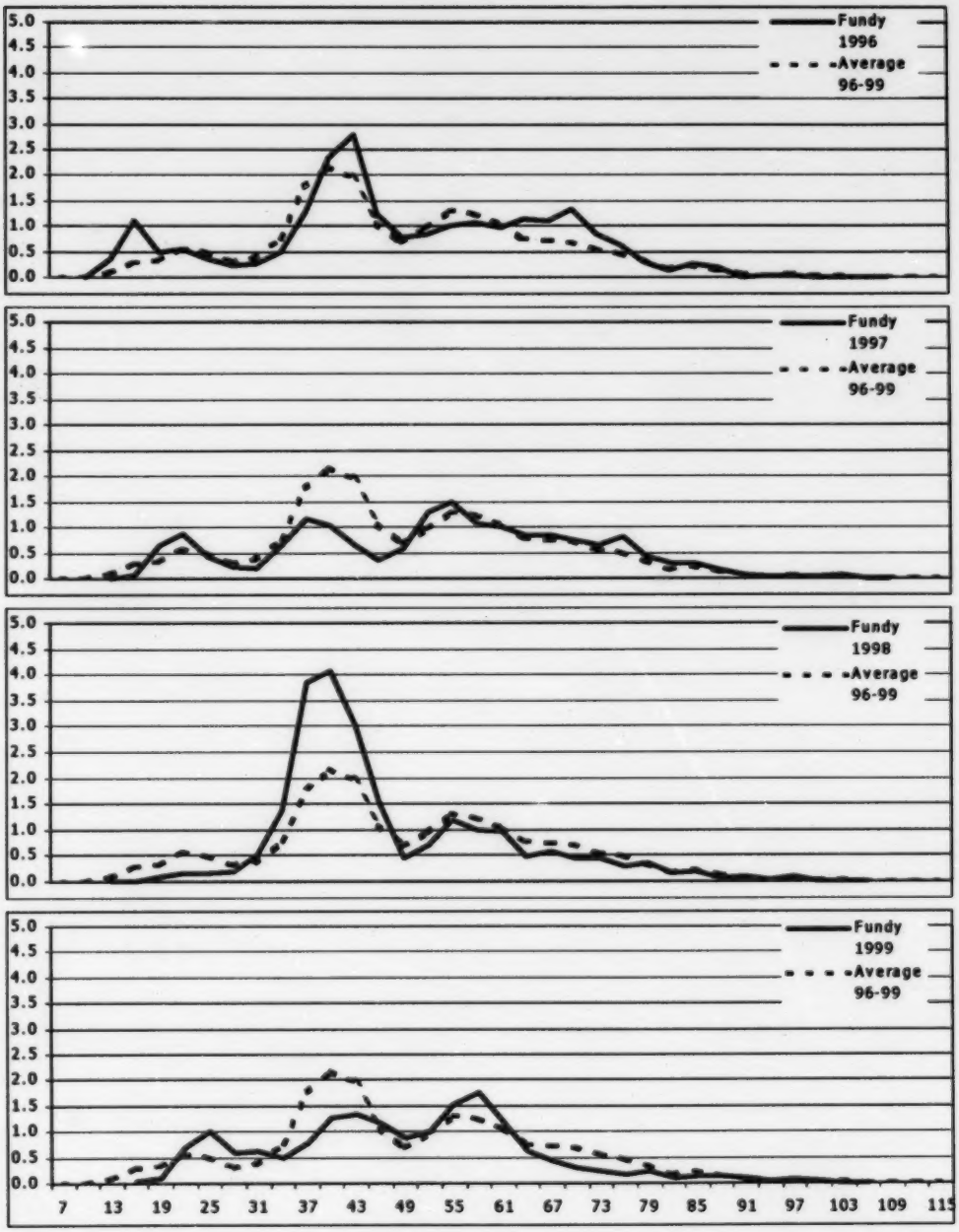

Fig. 16b. Bay of Fundy length frequencies and mean length at age from the ITQ surveys conducted in Division 4X; common sets from 1995-1999, n=124.

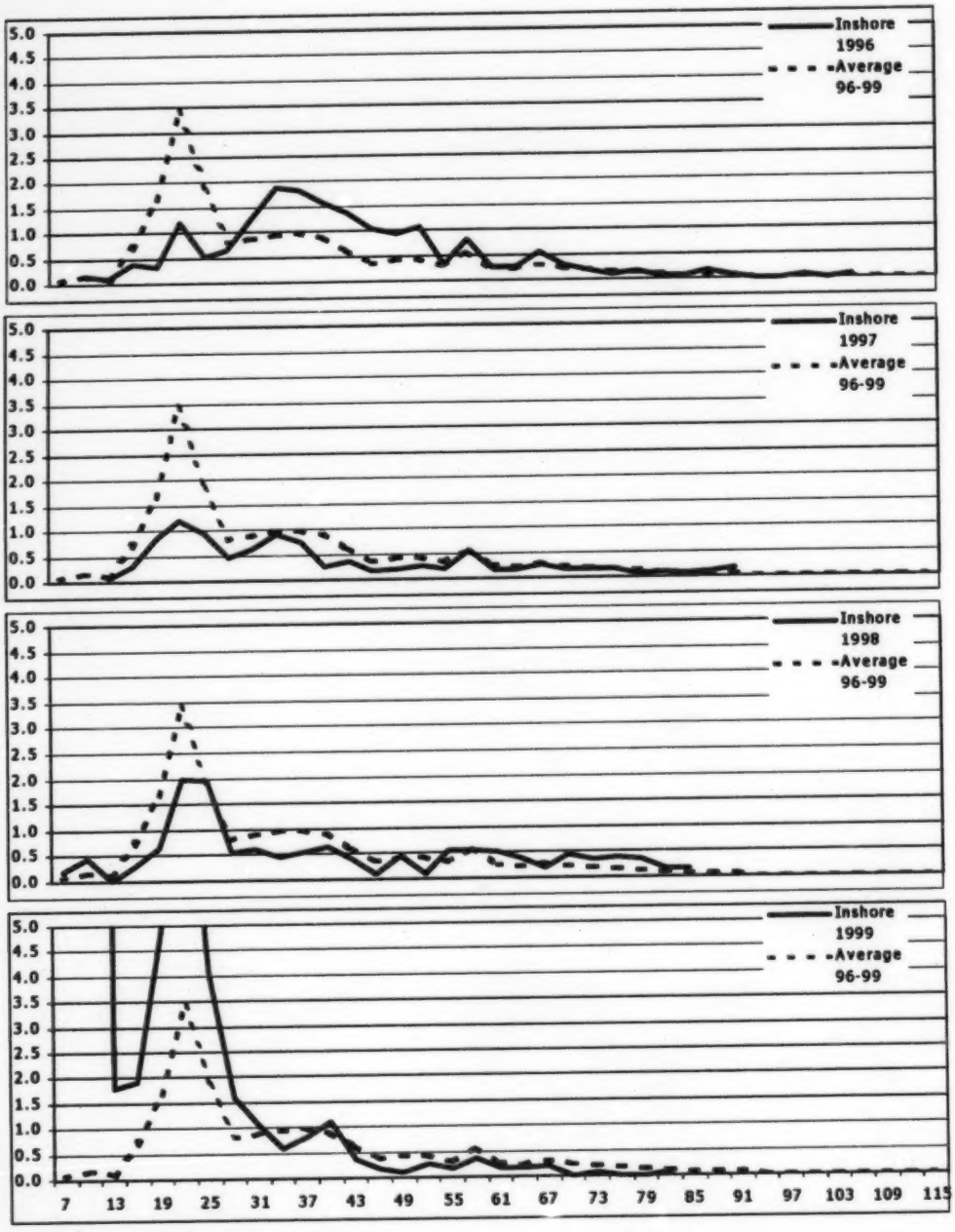

Fig. 16c. Inshore length frequencies and mean length at age from the ITQ surveys conducted in Division 4X; common sets from 1995-1999, n=124.

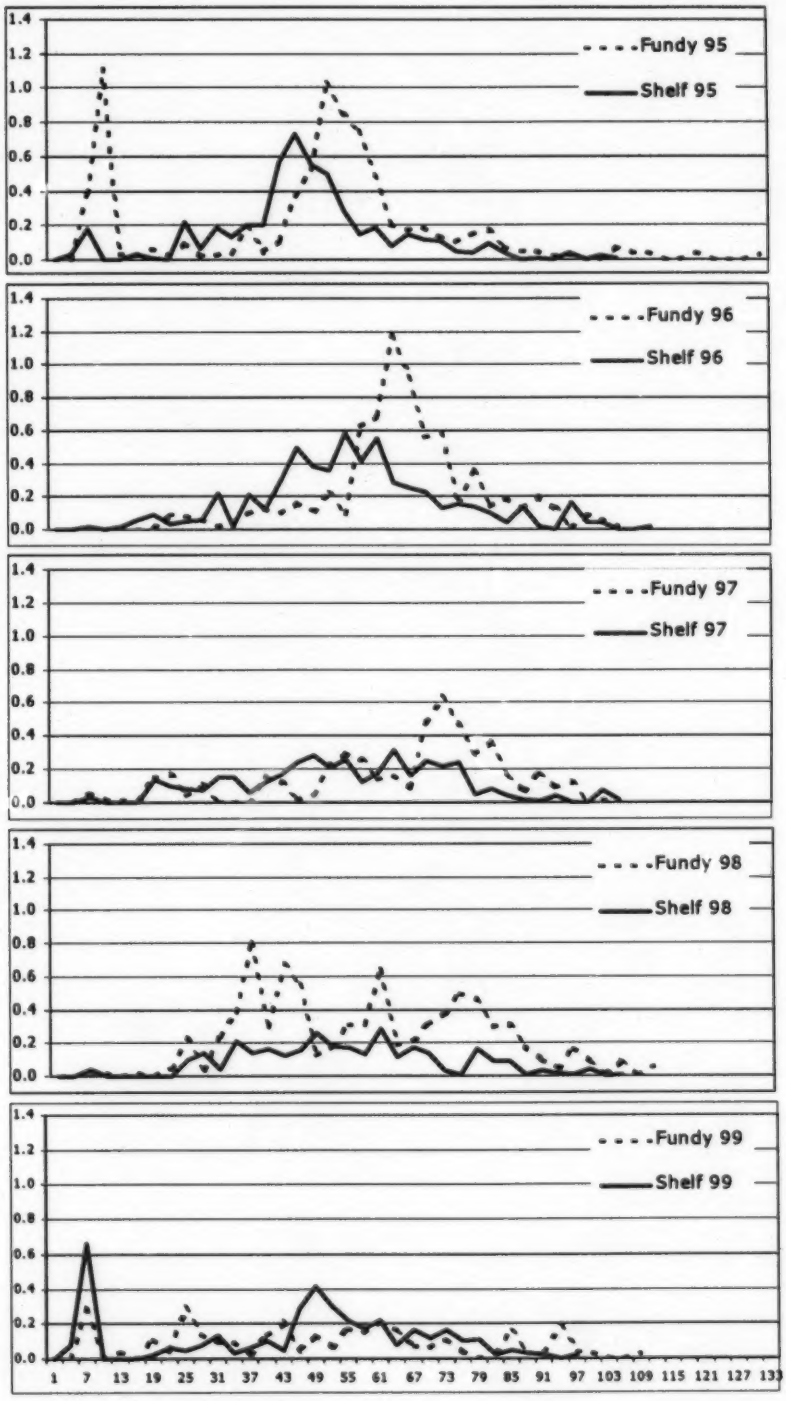

Fig. 17. Length frequencies from the summer groundfish survey in Division 4X.

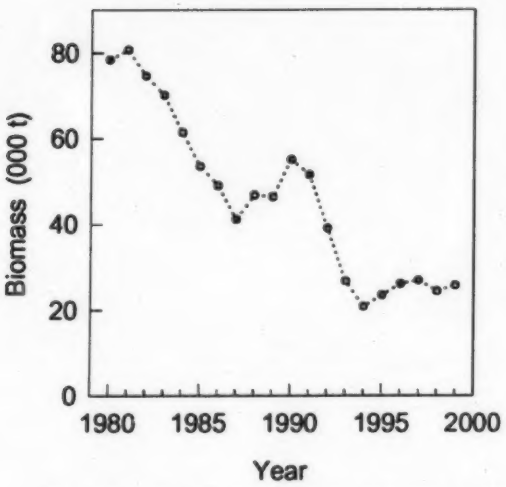

Fig. 18a. Beginning of year biomass (3+) for cod in Division 4X using the RV index (1983-1999) and the ITQ index (1995-1999).

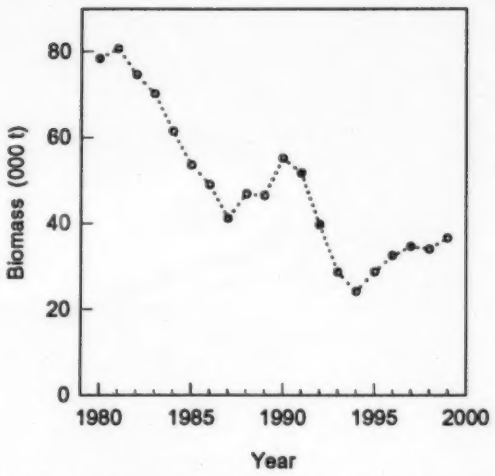

Fig. 18b. Beginning of year biomass (3+) for cod in Division 4X using the RV index (1983-1999), ages 2-7.

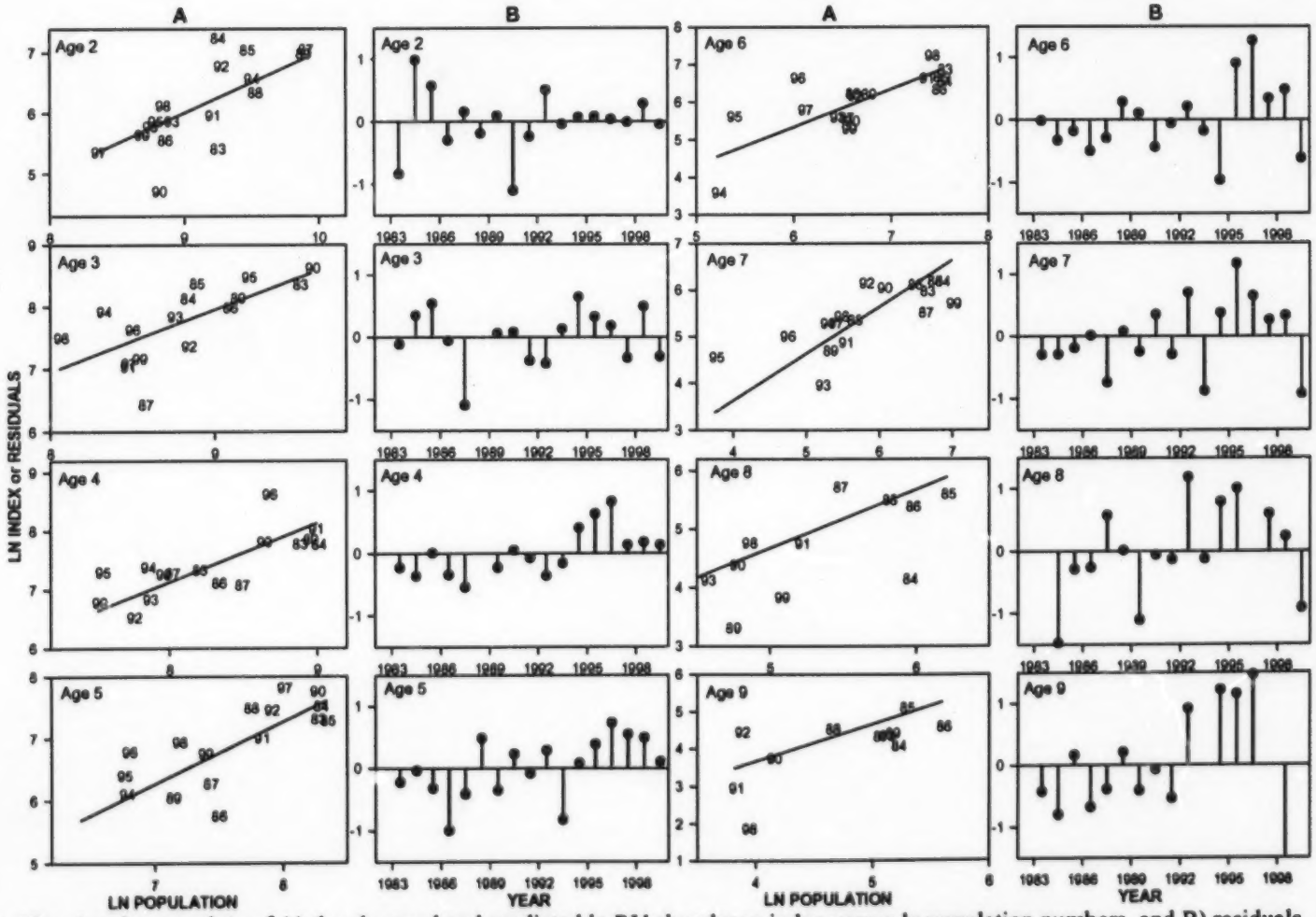

Fig. 19a. Age by age plots of A) the observed and predicted ln RV abundance index versus ln population numbers, and B) residuals plotted against year for cod in Division 4X and the Canadian portion of 5Y. RV index 1983-1999, ITQ index 1995-1999.

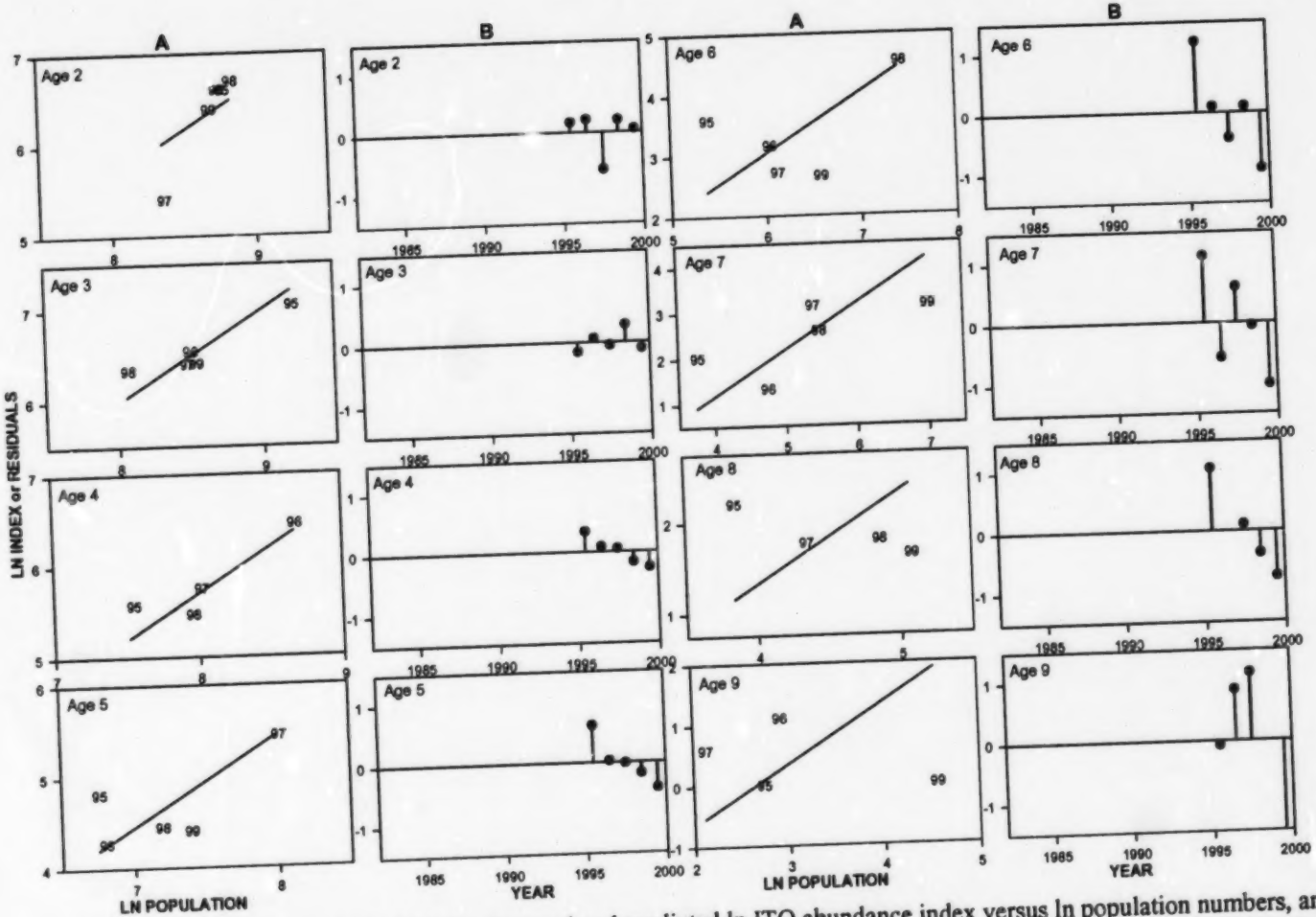

Fig. 19a (cont). Age by age plots of A) the observed and predicted ln ITQ abundance index versus ln population numbers, and B) residuals plotted against year for cod in Division 4X and the Canadian portion of 5Y. RV index 1983-1999, ITQ index 1995-1999.

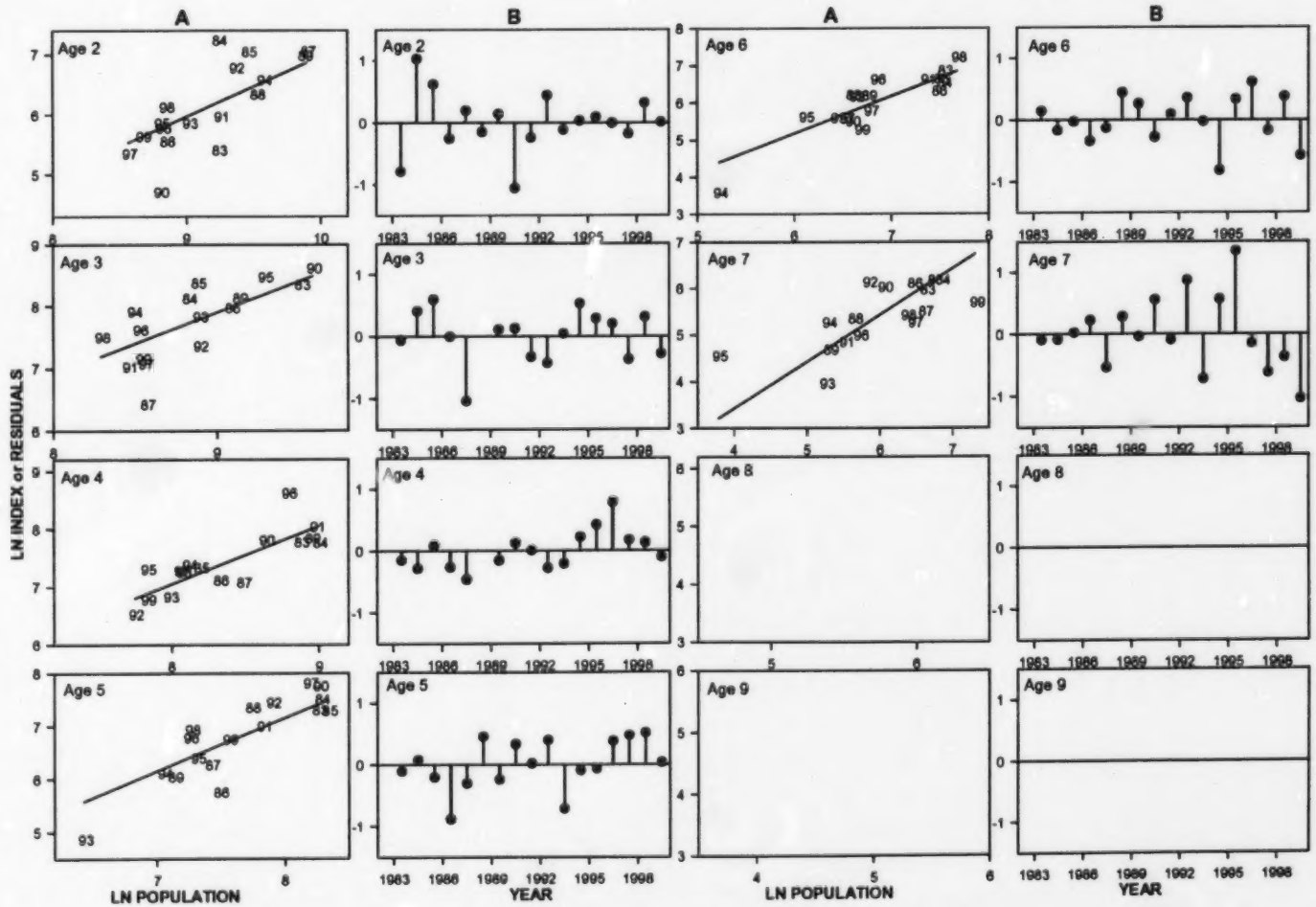

Fig. 19b. Age by age plots of A) the observed and predicted ln RV abundance index versus ln population numbers, and B) residuals plotted against year for cod in Division 4X and the Canadian portion of 5Y. RV index 1983-1999, ages 2-7.

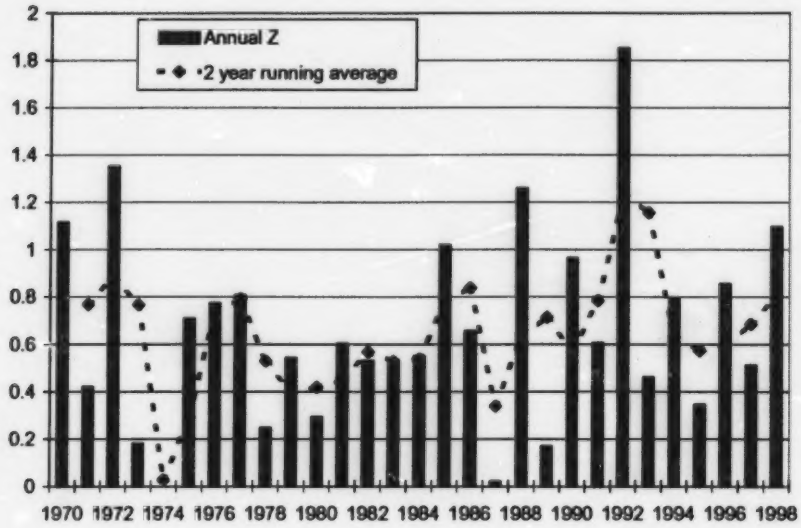

Fig. 20. Summer groundfish research survey Z (2 year running average) for ages 4+.

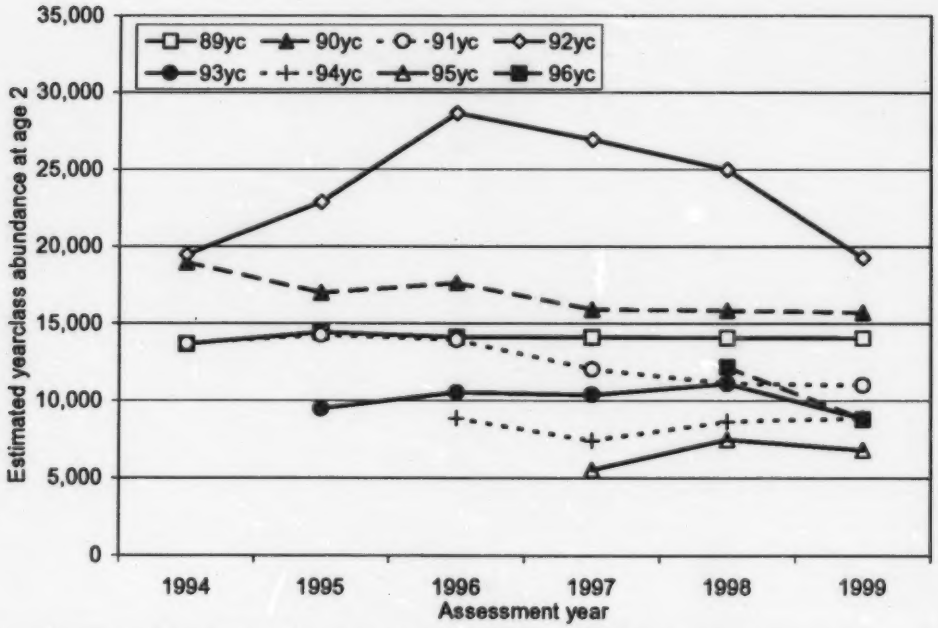

Fig. 21. Retrospective plot for 4X cod with RV survey index (1983-1999), ages 2-7.

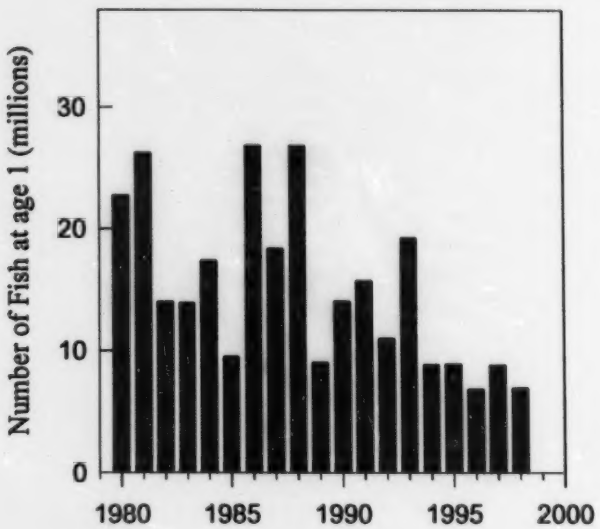

Fig. 22. Recruitment (age 1) for cod in Division 4X using the RV survey index, ages 2-7.

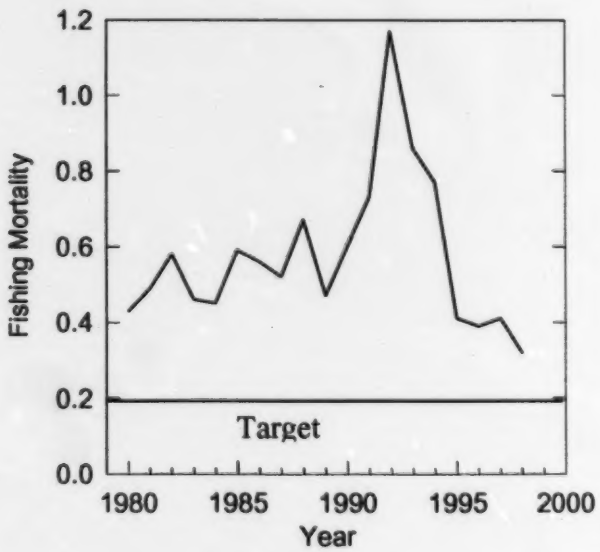

Fig. 23. Fully recruited fishing mortality (F) for 4X cod using the RV survey index (1983-1999), ages 2-7.